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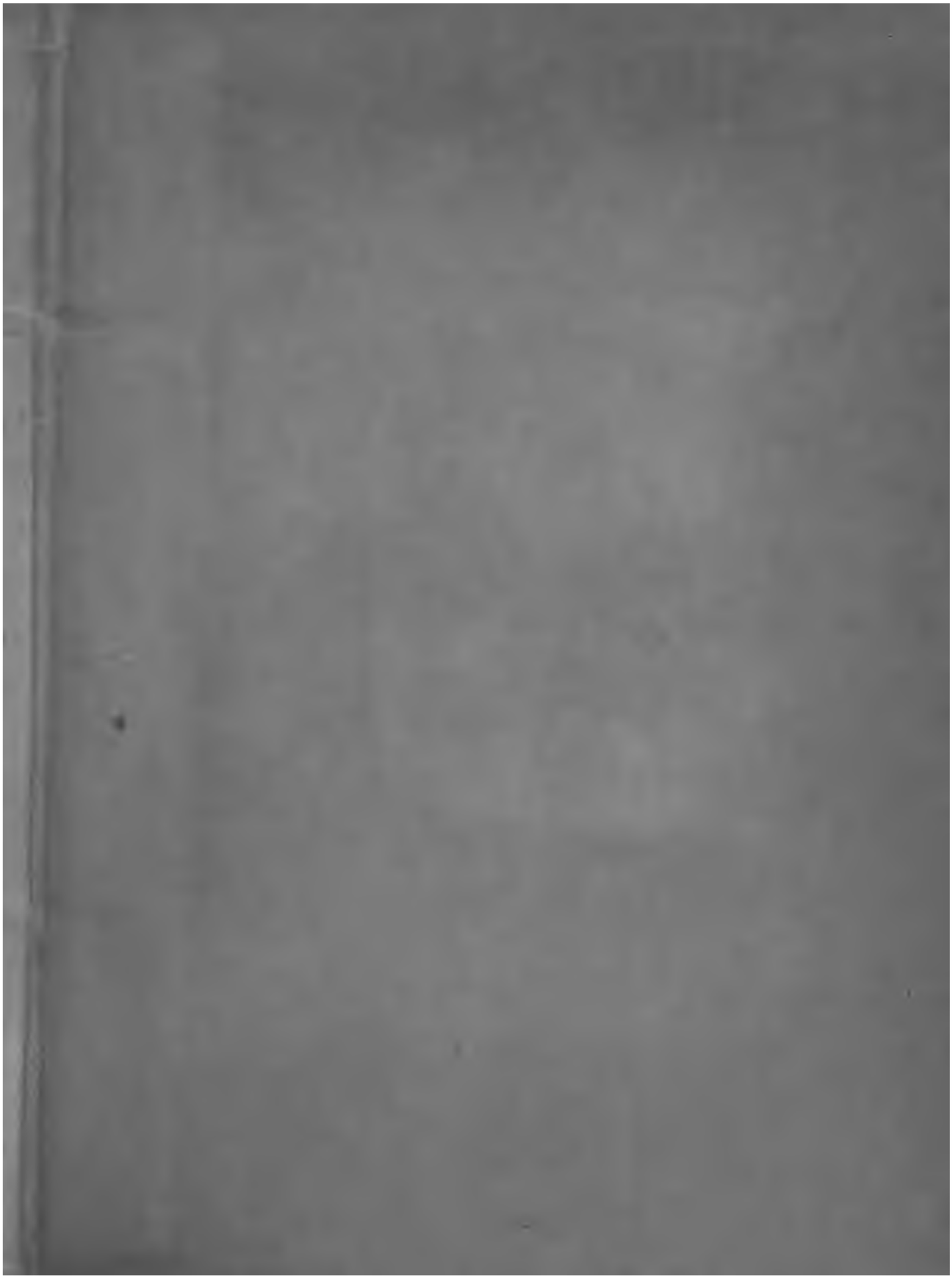

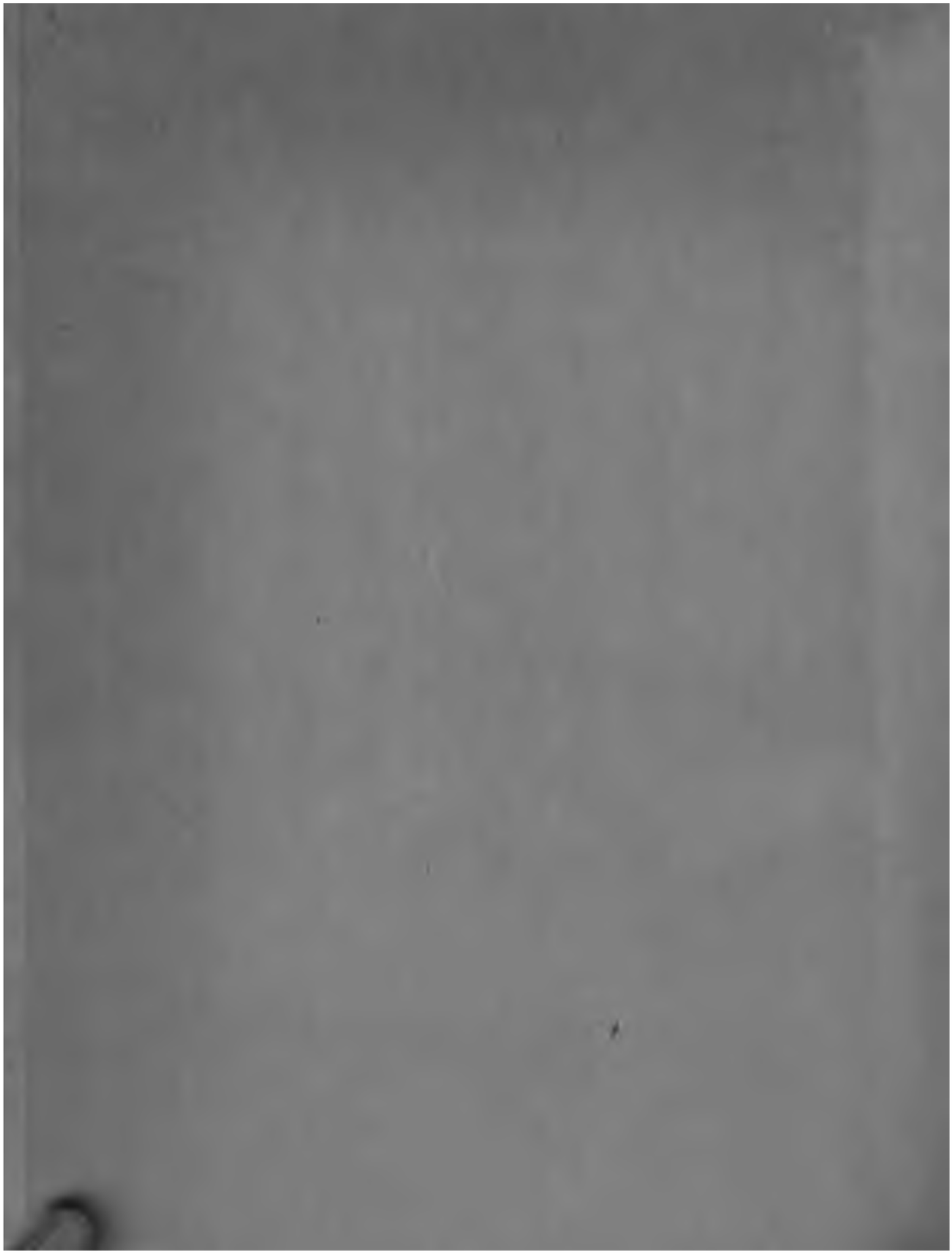

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

RECONNAISSANCE

FROM

FORT HAMLIN TO KOTZEBUE SOUND, ALASKA

BY WAY OF

DALL, KANUTI, ALLEN, AND KOWAK RIVERS

BY

WALTER C. MENDENHALL

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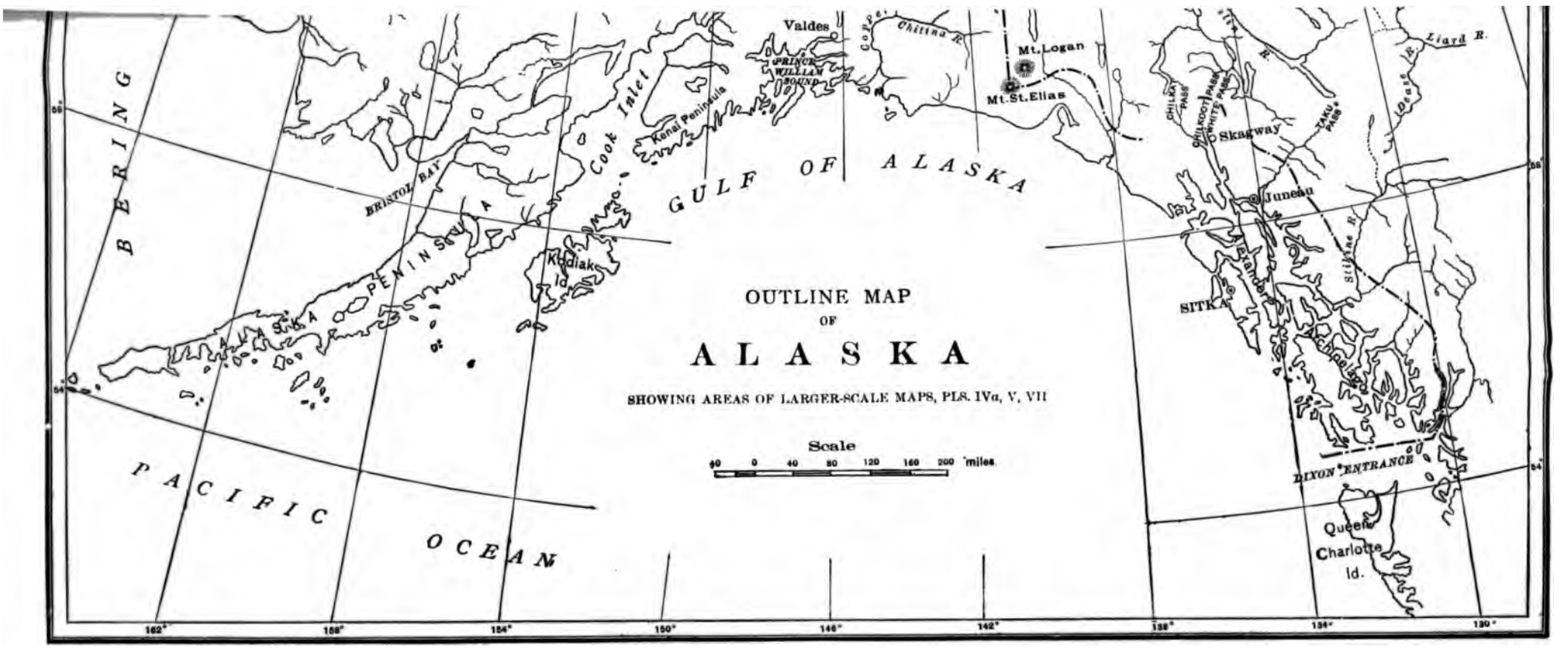
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RECONNAISSANCE FROM FORT HAMLIN TO KOTZEBUE SOUND, BY WAY OF DALL, KANUTI, ALLEN, AND KOWAK[a] RIVERS.

By WALTER C. MENDENHALL.

INTRODUCTION.

The reconnaissance described in the following pages was carried out in pursuance of a plan which has been followed for some years by the United States Geological Survey in the topographic and geologic exploration of the little-known parts of Alaska and in the collection of such information as will be of value not only to the scientific world, but to the prospector, the miner, and the trader. Capital disappears and years are wasted by prospectors who push out beyond the shifting frontier and pursue their search for gold where gold is not to be expected, and lives are being continually lost because the location and character of trails, drainage ways, and mountain ranges and passes are unknown, or because the knowledge which a few possess is not in a form available for the use of others.

Gradually the great waterways and mountain systems are being mapped, and reliable information is being gathered concerning the distribution of timber, the number and character of the native inhabitants, and the presence or absence of game—all matters of vital interest to the traveler who, whatever his object, ventures away from the great central waterway of the Yukon or from the trading stations on other streams.

An important object of the work in the region under consideration is to contribute to the increasing but as yet inadequate knowledge of the interior of the great Territory, and to present such conclusions concerning the known and probable distribution of mineral wealth as are justified by a hasty reconnaissance.

Those immediately responsible for the work, Mr. D. L. Reaburn and the writer, desire to express their appreciation of the cheerful service rendered at all times, and often under trying circumstances, by the other members of the party, Messrs. R. C. Applegate, W. B. Reaburn, W. W. Von Canon, George Revine, and W. L. Poto, without whose individual and collective cooperation the results

[a] This river is known as the "Kobuk" or "Kovuk" by the natives, prospectors, and traders. In this report the name Kowak is used, in accordance with the decision of the U. S. Board on Geographic Names. See Geographic Dictionary of Alaska: Bull. U. S. Geol. Survey No. 187, p. 250.

secured would not have been possible. Many others have also given information or aid and extended courtesies, but from among these many friends it is not possible to select names for especial mention, for the friendly hand is always extended by the Alaskan pioneer.

ITINERARY.

The party assembled in Seattle about the middle of May, 1901, and on May 19 took passage on the steamer *City of Seattle*, arriving at Skagway on the 23d. It was learned that Lake Laberge was still covered with ice and that steamers would not be able to get through until about the 10th of June. The Yukon River from Lower Laberge to Dawson, however, had been open since May 23. Being extremely loath to lose the ten days which remained before Lake Laberge would be navigable, canoes were purchased at White Horse, and with these the trip through Lake Laberge was made during the last of May and the early part of June. Open water was found between the ice and the shore for much of the distance, and where these channels had been closed by the crushing of the floe against exposed points the boats were placed upon rude runners and hauled over the ice until open water again appeared.

Finding the steamer *Bailey* waiting for outside mail at Lower Laberge, the party embarked on the 2d of June and reached Dawson early on the 4th. Here the party was divided, and Mr. Reaburn, with three men, was equipped with provisions and boats for running a stadia line from Fort Yukon to Fort Hamlin. This portion of the party left Dawson on the 5th of June on the steamer *Louise*, and began its work at Fort Yukon on the 8th.

The remaining members of the party stayed at Dawson until June 10, buying supplies and securing information concerning the country between the mouth of Dall River and the Koyukuk, which was to be traversed later. A brief visit was made to the producing creeks near Dawson. On the evening of the 10th the party left Dawson and arrived at Fort Hamlin on the morning of June 13. Three weeks' supplies were purchased here for the trip to Bergman, and on the 17th the party was reunited by the arrival of Mr. Reaburn and his assistants.

June 18 to June 27 were spent in carrying the traverse line up the Dall River to the collection of cabins on its upper course known as Dall City. Here the overland pack trail from Fort Hamlin to the Koyukuk diggings crosses the river, and prospectors were found, bound for the Koyukuk diggings, but entirely ignorant of the route to be followed in reaching them.

By the evening of July 3 the entire outfit had been transported over the 18 miles of portage to a point on the Kanuti River where boats with their loads would float. The stream here, however, was swift, shallow, and full of bowlders, so that boats could be taken through it only with the greatest care, and even then

A. TRACKING ALONG THE EDGE OF THE ICE, LAKE LABERGE.

B. ROUNDING A BAD POINT, LAKE LABERGE.

at some risk. On the 5th of July a broad valley along the upper course of Kanuti River was reached. Here the stream wanders in tortuous meanders, and as there was abundant water, good progress was made. On the next day rapids were encountered, which extend for a distance of 25 or 30 miles, and in which there is a fall of 700 to 800 feet. Through much of this distance the stream is a practically continuous rapid, full of large bowlders, and most careful work was required to get the boats through without wrecking them completely. Notwithstanding the utmost care they were punctured several times, and in two or three instances were swamped, although without much damage to outfit or provisions. The most serious feature of this section, however, was the delay which it occasioned and the consequent exhaustion of supplies, so that by the time the more easily navigable lower portion of the river was reached, on the 10th of July, provisions were nearly gone, and in order not to interrupt the work recourse was had to the game and fish supplies of the river. Fortunately, ducks and geese were abundant, and these furnished the greater portion of the subsistence for the last few days spent on the Kanuti River. At the mouth of Mentanontli Creek a fishing party of Koyukuk Indians was encountered, and from these a few pounds of flour and bacon were purchased.

On the 15th of July Bergman was reached. Here the supplies for the summer, shipped in during the previous year, were found in excellent condition, and the next three days, until the 18th, were spent in fitting up the canoes, packing supplies, securing information, and generally preparing for the principal task of the summer, which was still ahead. Through the good offices of Mr. James Powers, the agent of the Alaska Commercial Company, the services of John, a Kowak native, familiar with the portage from the Allen to the Kowak waters, were secured. With the supplies loaded into four boats the party left Bergman on the 18th of July and camped that night a short distance above the mouth of the Allen.

The trip up the Allen was without special incident, the stream, although swift, being free from serious rapids and usually having along its shores bars sufficiently broad to give good tracking. On the 24th of July the mouth of Helpmejack Creek, 90 miles from Bergman by water, was reached, and on the next day the ascent of the creek was begun. At the head of this stream is the pass leading to the Kowak. On the 30th of July, after making double trips along a portion of the shallower upper waters of Helpmejack Creek, the party camped at the eastern end of the portage, which is only 5½ miles in length and involves a climb of only 300 feet. On the 2d of August, while encamped at the halfway point on the portage, a forest fire, started in the dry moss from a carelessly placed smudge, seriously threatened for a time to destroy the camp

and its supplies. The fire was eventually beaten back, not, however, until two tents and practically all the contents of one of them, including sleeping bags and the heavy clothing of three of the men, had been lost. By redistributing the clothing on hand and making blankets of the burnt fragments of sleeping bags remaining, the members of the party who had suffered most from the fire were again equipped, so that during the remainder of our trip there was no serious inconvenience. While at Bergman a packer and his horse had been engaged to meet the party on the portage and help transport the outfit, but he did not reach the camp on the portage until the 5th of August, in time to help with but one day's packing.

On the 8th the party started down Kichaiakaka Creek, on the west side of the divide, and on the morning of the 10th reached the Kowak River, which at this point is a beautifully clear mountain stream, 125 feet in width and 6 or 8 feet deep. During the afternoon of that day the party descended the river as far as the outlet of Walker Lake, passing en route two rapids. Around one of these it was necessary to portage, but through the other the boats were lined in safety. On the 11th of August the camp was moved up Walker Creek to the rapids about a mile below the southern end of the lake. The next day the empty canoes were taken through this barrier and almost to the upper end of the lake, which was discovered and mapped by Cantwell in 1885.

With the uncertainty as to the length of the river yet to be traversed before reaching Kotzebue Sound, and conditions of transportation after we should arrive there, we felt it unwise to spend more time here near the headwaters of the Kowak, and accordingly resumed the journey downstream on the 13th of August. The party looked forward rather anxiously to the passage of the gorge some miles below us, which Cantwell had described as particularly difficult, and in which he came near losing one of his men. John, too, although an excellent boatman, had not traversed this upper portion of the river during the summer season, and evidently had received rather alarming accounts of its difficulties from his native friends, so that the party was greatly relieved when, on the 14th of August, the head of the mile-long canyon was reached and it was found that its passage in light canoes was not at all a serious matter. After an hour's work the entire outfit was taken through, one slight puncture being the only mishap.

On the 17th the native village at the mouth of the outlet of Lake Selby was reached, and the following day camp was held here while a visit was made to the lake 5 miles to the north for geologic and topographic work. The journey downstream was not again interrupted until the mouth of the Ambler River was reached, on the 23d of August. Between Lake Selby and the Ambler many native fishing villages were passed. There are also many well-built cabins scattered

A. A RIFFLE, DALL RIVER.

B SLEDDING ON LAKE LABERGE.

in use on the charts. Among them are Chamisso Island, Eschscholtz Bay, Cape Deceit, Asses Ears, Devil Mountain, Capes Krusenstern and Espenberg, and Goodhope Bay.

Ten years after Kotzebue's discovery Capt. F. W. Beechey,[a] commanding the *Blossom*, entered the sound in furtherance of his work of charting the northwest coast of America. He added considerably to the knowledge of Kotzebue Sound and produced a chart which has been the basis of all subsequent maps of the region. He discovered and named the Buckland River, in September, 1826, and examined and chartered the shores of Spafarief Bay during the same month. He examined the ice cliffs off Elephant Point, which had been described by Kotzebue, and mentions those of Cape Blossom. Some geologic notes of value are given by him, in which he describes the schistose series outcropping in the neighborhood of Cape Deceit as talc slates and limestones, and mentions the occurrence of vesicular olivine lava along the shores of Goodhope Bay. Mr. Elson, of the *Blossom*, explored Hotham Inlet, which Kotzebue had failed to note, and reported that it was 30 or 40 miles in length and that the water at its upper end was fresh.

The *Blossom* left Kotzebue Sound on October 13, 1826. The work along the shore and northward not being completed this year, Beechey returned the following season, but made no important additions to his work of the previous summer.

Some of the best geographic work which has been done in the northern portion of North America was accomplished in connection with the series of relief expeditions sent out by the British and other governments in search of Sir John Franklin, who made an unsuccessful attempt to discover a northwest passage. The greater part of this work was accomplished in the region near Hudson Bay, but through some of the expeditions on the west coast of the continent substantial contributions were made to our knowledge of the geography of the coast in the vicinity of Bering Strait.

On the 9th of September, 1849, Capt. Henry Kellett, commanding H. M. S. *Herald*, at that time in Kotzebue Sound, started with several boats' crews to visit the natives reported to live some distance up the Buckland River. Captain Kellett himself ascended the stream about 30 miles, until a rock obstruction which prevented the passage of the heavier boats was encountered. He then returned and Commander Moore, of the *Plover*, and Lieutenant Maguire, of the *Herald*, with lighter boats ascended about 30 miles farther, passing several rapids en route. These officers reported that the river contained several obstructions within the 60 miles explored by them, and at the head of this stretch a strong

[a] Narrative of a Voyage to the Pacific and Beering's Strait, by Capt. F. W Beechey.

rapid, half a mile in length, through which they could not pass. Pine [spruce] trees were reported as occurring sparingly in the Buckland Valley, and an account is also given of the presence of fine basaltic columns along the river.[a]

The *Plover*, under Commander Moore, spent the winter of 1849–50 in Kotzebue Sound, and Lieutenant Pim was detached from the *Herald* to remain with her. During the winter various minor expeditions were undertaken by the officers and men, the object being in most cases to ascertain the truth of native rumors to the effect that white men who might belong to the missing expedition had been seen in the interior. In the course of these trips Hotham Inlet and the Spafarief [Keewalik] River were visited and mapped in part.

The two most important trips made this winter were those of Lieutenant Pim and Mr. Simpson. Lieutenant Pim[b] started overland on the 4th of March by way of the Spafarief River to St. Michael, which he reached, after many hardships, on the 6th of April. He returned to the ship on April 29. His journal gives a circumstantial account of the country which he traversed, but no chart of the route was prepared. Mr. John Simpson[c] left the vessel, which at the time was anchored on the east side of Choris Peninsula, on the 13th of May, with dogs and sledges, and returned to the ship on the 25th. In the interim he explored the head of Hotham Inlet and Selawik Lake, to the latter of which he gave the native name of the river emptying into it. He mapped the shores of the lake, which is about 5 miles wide and 15 miles long, and ascended the Selawik River for a mile and a half, describing its valley and the hills to the north and south of it, which he could see plainly from a small eminence. Simpson's account is the first mention in literature of the Kowak River, which he called Kowuk. He located the eastern and largest outlet of this stream, which he described as 400 yards in width and having a current of 2 miles per hour. He traced its course for many miles by its border of tall "pines," and was informed by natives of the existence of a village seven days' journey up the stream. A map embodying the results of his geographic observations accompanies his paper.

Commander Moore was promoted during the summer of 1852 and relieved of command of the *Plover*, to which Commander Maguire was assigned, and the vessel was then ordered to Point Barrow, where she spent the two succeeding winters. While stationed here, short expeditions were made along the coast east and west, and an expedition into the interior to a point 40 miles south and 38 miles west of Point Barrow. Again the most important contribution to the

[a] Narrative of proceedings of Captain Kellett, of H. M. S. *Herald*, and Commander Moore and Lieutenant Pullen, of H. M. S. *Plover:* Great Britain, Parliamentary Papers, session of 1854–55, vol. 35.

[b] Voyage of the *Herald*, by Berthold Seaman.

[c] Journal of Mr. John Simpson, surgeon of H. M. S. *Plover*, in command of a detached party to the eastern head of Hotham Inlet in May, 1850: Great Britain, Parliamentary Papers, session of Feb. 3 to July 1, 1852, vol. 50.

geography of the region was made by Mr. Simpson, who was attached to the *Plover* in the capacity of surgeon.[a] In this paper Mr. Simpson described the natives from Cape Prince of Wales north and east to the mouth of the Colville, chiefly from data gathered at Point Barrow, and assembled information which he obtained from these natives on a map, on which the courses of the Noatak, the Kowak, the Selawik, the Colville, and other streams are shown with much fidelity.

Commander Trollope, of H. M. S. *Rattlesnake*,[b] started from Port Clarence, where the *Rattlesnake* was wintering, on the 9th of January, 1854, on a sledging trip to Cape Prince of Wales, which he reached on the 18th of the same month. His object was to communicate, if possible, across the strait with Siberia. No maps resulted from this trip, but interesting notes are given about the natives. William R. Hobson, mate of the *Rattlesnake*,[c] made a difficult journey overland from the ship to Chamisso Island, in Kotzebue Sound. He started on the 9th of February and returned on the 27th of March, having traveled in forty-seven days a distance of 560 miles (estimated). This trip was the more remarkable because for the greater part of the time he had to depend for food on the natives encountered and the game secured, and even now, under modern conditions, with abundance of road houses along the route, it tests the endurance of the hardiest prospector. Mr. Hobson unfortunately prepared no maps of the route traversed, although he gives abundant notes concerning the country and the natives.

With the close of this long series of relief expeditions, work of an exploratory character in the region of Kotzebue Sound ceased for many years. The Western Union telegraph expeditions passed a short distance to the south of the area under consideration, but made no contributions to Kotzebue Sound geography.

In the years 1884–1886, however, a series of exploratory expeditions along the Kowak Valley were carried out by Lieut. George M. Stoney, of the United States Navy, and by Lieut. J. C. Cantwell, of the Revenue-Marine Service.

Lieutenant Stoney's first visit[d] was made in the *Corwin* in 1883 as a member of an expedition sent out in connection with the *Jeannette* relief. The *Corwin* left him at the mouth of Hotham Inlet with one white companion and seven days' provisions. He spent fifteen days in the country and reached the head of the delta 45 miles from the mouth of the river.

The next year, after giving an account of his discoveries and requesting permission to continue the work, he returned in the schooner *Unalaska* and

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[a] Observations on the Western Eskimo, and the country they inhabit, by Mr. John Simpson, surgeon, R. N. H. M. S. *Plover:* Great Britain, Parliamentary Papers, session of 1854–55, vol. 35.

[b] Great Britain, Parliamentary Papers, session of 1854–55, vol. 35.

[c] Ibid.

[d] Naval Explorations in Alaska, by Lieut. George M. Stoney, U. S. Navy, 1900.

A. LOWER END OF KOWAK RIVER GORGE.

B. LOOKING TOWARD HEAD OF WALKER LAKE FROM 2 MILES BELOW ITS WESTERN END.

In the background are mountains of schist and limestone.

undertook the exploration of the Kowak River with a steam cutter and a native skin boat of 6 tons' capacity. After ascending about 275 miles, the current became too strong for the cutter, and it was left behind. The journey was continued, however, in the skin boat, until the Soolookpowuktoark River (outlet of Lake Selby) was reached. Stoney visited the lake drained by this stream and then returned down the Kowak to Hotham Inlet. He sent Ensign Purcell to explore Selawik Lake and another east of it, which was called the Inland lake. This done, the party returned to San Francisco. During the next summer, 1886, Lieutenant Stoney went again to the Kowak, established winter quarters about 250 miles up that stream, at Fort Cosmos, and during the following winter parties conducted either by himself personally or by his officers carried out extensive explorations in the surrounding country. The principal of these explorations were by way of the Ambler River to Nimyuk on the Noatak, up the Kowak through a pass near its head to the Allen, which belongs to the Koyukuk system, and northward from its source to Chandlar Lake, and southward to the middle course of the Selawik. These three trips were conducted by Lieutenant Stoney in person. Besides these, Ensign Howard, under Lieutenant Stoney's direction, made a trip to Point Barrow in the spring by way of the Upper Colville and Chipp rivers, which he mapped en route; and Assistant Engineer Zane journeyed to St. Michael by way of the Pah, Koyukuk, and Yukon rivers. These combined expeditions resulted in the acquisition of definite geographic knowledge of this territory, which before this had been practically unknown.

Lieut. John C. Cantwell,[a] of the Revenue-Marine Service, entered one of the mouths of the Kowak July 10, 1884, and explored the river to a point some distance beyond the mouth of the Black. A small steam launch and a skin boat were used. The launch became disabled, and the party returned without reaching the large lakes in which the river was reported to rise.

The second expedition in command of Lieutenant Cantwell, for the exploration of the Kowak, left the *Corwin* on July 2, 1885.[b] Lieutenant Cantwell used, as in the previous year, a steam launch and a skin boat, the launch having been specially prepared for the work. On the 16th of July he reached the lower rapids of the Kowak, which he passed after an accident which nearly proved fatal to one of the natives who accompanied him, and on the 21st reached the outlet of Walker Lake. This he ascended as far as the rapids. A couple of days were spent in the neighborhood of the lower end of the lake, which was mapped from the top of one of the neighboring peaks; then a short portage was made to the Kowak above the mouth of the Kichaiakaka. He reported the

[a] Report of the cruise of the Revenue-Marine steamer *Corwin* in the Arctic Ocean in the year 1884.

[b] Exploration of the Kowak River, Alaska, by Lieut. J. C. Cantwell: Report of cruise of the revenue steamer *Corwin* in the Arctic Ocean in 1885, pp. 21–52.

Kowak to be here a small stream 50 yards wide and 1 foot deep. Having completed his explorations on the upper river, he returned to his launch, which had been left below the mouth of the Pah, and on the 27th rejoined the steamer. An expedition under Engineer McLenegan, of the *Corwin*, had been carried out at the same time on the Noatak River. Maps accompany the reports, which give the results of the geographic work in the valleys of the two streams.

The work of Lieutenants Stoney and Cantwell, who were pioneers in this region, north of the Arctic circle, is most valuable, and to the workers themselves a maximum of credit is due, since they were penetrating territory about which nothing was known except from inaccurate native accounts, so that no adequate provision could be made for meeting conditions encountered.

An historical sketch of the Kotzebue Sound region would not be complete without mention of the remarkable journey of Lieutenants Jarvis and Bertholf, Dr. Call, of the revenue cutter *Bear*, and W. T. Lopp, missionary at Cape Prince of Wales, in connection with the expedition for the relief of the whalers imprisoned at Point Barrow in the winter of 1897–98.[a] A midwinter journey of about 1,500 miles was made from the coast north of Bristol Bay to Point Barrow, and several hundred reindeer intended for food for the imprisoned whalers were driven from the region about Port Clarence.

In 1898 the Kowak River Valley was the scene of a stampede, brought about by reports to the effect that gold in paying amounts existed in the valley of the river. Mr. McIlwaine[b] reports that about 1,200 people took part in that stampede, and gives in popular form a brief account of the movement, its hardships and disappointments. Of the 1,200 people who reached Kotzebue Sound, about 800 spent the winter of 1898–99 on the Kowak, but few indications of the presence of gold were found. In the spring practically all the prospectors departed, the majority went down the stream and out of the region by way of Kotzebue Sound, but a few went up the river to the passes at its source and then down the Koyukuk River. Since that time a very few white men have been on the stream each summer, and the river steamer *John Riley*, commanded by Captain Coogan, has spent two winters there, and again wintered in the neighborhood of Black River during the season of 1901–2.

The Yukon is now, and within historical times has been, the highway followed by the trader and the explorer in the interior; hence its geography became known early in the history of interior work. Lieutenant Zagoskin's map of the lower river, prepared about 1843, extends up to a short distance above Nulato. The Western Union Telegraph Company's map of 1869 is based in part upon it. Mr. Whymper's, Dr. Dall's, and Captain Raymond's maps of

[a] Report of the cruise of the revenue cutter *Bear* and the overland expedition, 1897–98.
[b] The Truth about Alaska, by Eugene McIlwaine.

the Yukon below Fort Yukon followed in rapid succession, each map being a distinct improvement upon its predecessor. The astronomic positions as determined by Captain Raymond are still accepted as the basis for the charts of this part of the Territory. In addition to their contributions to geography Dr. Dall and Robert Kennicott also added notably to our knowledge of the natural history and ethnology of the Yukon Basin. Among later geographers, Lieutenant Schwatka and Mr. Homan are to be mentioned, Homan's survey of the Yukon, made in 1883, being the basis of the present maps of the river. Lieut. H. T. Allen,[a] in 1885, after ascending the Copper River and descending the Tanana, made the overland trip from a point 6 miles below Nuklukayet on the Yukon to the junction of the Mentanontli and Kanuti rivers. He was accompanied by one soldier, Fickett, and 7 natives, and the journey was made in a little more than six days. From the mouth of the Mentanontli he descended the Kanuti River and continued his work up the Koyukuk to the mouth of the Totsenbet River. At this point he turned back, drifted down the Koyukuk, and reached Nulato on the 21st of August, 1885, having contributed to the world, as a result of his remarkable work this summer, the first definite knowledge of the basin of the Koyukuk as well as of the Tanana and Copper.

In 1889 Professor Russell[b] accompanied the Coast and Geodetic Survey parties under McGrath and Turner, whose object was to establish on the Porcupine and Yukon rivers the crossing of the one hundred and forty-first meridian, the international boundary line. The trip involved the ascent of the Yukon from St. Michael to Lake Lindeman, and while opportunities for detailed geologic study were limited, a number of interesting and suggestive notes of a general nature resulted.

In 1896 Messrs. Spurr, Goodrich, and Schrader, of the United States Geological Survey, descended the Yukon, and in the report[c] which followed is found the first comprehensive study of the geology and of the physiographic history of the American Yukon Basin.

In 1899 F. C. Schrader[d] and T. G. Gerdine ascended the Chandlar River, portaged from near its head to Robert Creek, one of the upper tributaries of the Koyukuk, and descended the latter stream to its mouth. Previous to this the Chandlar was practically unknown, and but little accurate information was available concerning the Koyukuk beyond the point reached by Lieutenant

[a] Report of a military reconnaissance in Alaska, made in 1885 by Lieut. Henry T. Allen, U. S. Cavalry.

[b] Notes on the surface geology of Alaska, by Israel C. Russell: Bull. Geol. Soc. America, Vol. I, pp. 99–162.

[c] Geology of the Yukon gold district, Alaska, by J. E. Spurr: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 87–392.

[d] Preliminary report on a reconnaissance along the Chandlar and Koyukuk rivers, Alaska, in 1899, by F. C. Schrader: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 441–486.

Allen in 1885. The result of this reconnaissance appears in a complete topographic map of the field traversed, with comprehensive data on the geology, economy, and mining developments in the drainage basins of both the Chandlar and Koyukuk.

Although the route from the Yukon to the Koyukuk by way of the Dall River has been known and used for a number of years by prospectors, and the headwaters at least of the Kanuti River have been visited by them, no maps of either stream were available, and no accurate information concerning them was obtainable previous to the year 1901.

The valley of the Allen has always been one of the lines of travel followed by the Kowak Indians when journeying to the Koyukuk in winter for purposes of trade, and several of the prospectors who wintered in 1898–99 on the Kowak came out to the Yukon by this route, but no maps had been prepared of it previous to our work there.

CONDITIONS AND METHODS OF WORK.

Exploring expeditions in high latitudes, which are carried on only in the summer, with no provision for wintering, are limited in time, and hence, where the extent of territory covered is considerable, in the present case between 1,100 and 1,200 miles, certain sacrifices must be made to the paramount necessity of gaining ground. Through difficult regions all the energies of the scientific, as well as of the other members of the party, are of necessity often devoted to overcoming the physical obstacles encountered.

Work under these conditions can not be uniform in quality. Observations made while the observer is struggling ahead at the end of a tracking line, or bending all his energies to the prevention of disaster in the wild waters of a gorge, or perhaps zigzagging up a 1,000-foot climb with 90 pounds on his back, are not always as complete as is desirable. It is hoped, however, that such conditions have not resulted in other inaccuracy than that due to incompleteness.

Geologic observations were for long stretches confined to the line of traverse, but wherever it was possible these were supplemented by side trips. Generally a rough compass traverse was maintained upon which observations were recorded directly; but at times when the geologist and topographer were together, references were placed upon the topographer's traverse and the geologic observations recorded with corresponding references. Collections were of course made for comparative study later, and information was gleaned from all possible sources.

For transportation Peterboro canoes were used, since the route lay along waterways or over portages where these light boats could be carried. Two were used from Fort Yukon to Bergman, and four from Bergman to Kotzebue Sound.

The canoes were propelled by oars, sails, or paddles, or by tracking or poling, as conditions varied.

Some photographic records were secured, although these are not as numerous nor complete as was desired because of the damage to instruments by water.

For temperature observations two standard thermometers were depended upon chiefly. A minimum thermometer was used during the early part of the season, but later was broken. The maximum was of little use because camp was moved practically every day, and no records could be secured from the instrument while it was packed in a moving canoe.

Plants were collected when conditions permitted and dried with such care as was possible, and brief notes on their distribution were recorded at the same time.

Distances were determined in all cases by micrometer and stadia measurements and by plane-table triangulation. A continuous line was maintained from Fort Yukon on the Yukon River to the mining village of Deering on the south shore of Kotzebue Sound. The total distance thus traversed, including two side trips, one to the head of Walker Lake and the other for a short distance up the Ambler River, was 1,169 miles. This involved two portages, one from the head of the Dall River to the head of the Kanuti River, a distance of 18 miles over a divide 2,500 feet high, and the other from the head of Helpmejack Creek to the upper course of the Kichaiakaka, a distance of 5½ miles, over an elevation of 300 feet.

Elevations were determined by vertical angles, and the results of these determinations are shown on the maps by contours. Sights in some instances were long, making exact work impossible, but the error can not in any case be great. The elevation of Fort Yukon was assumed as a starting point to be 500 feet above mean sea level. This assumption was based in part upon data furnished by ex-Governor Ogilvie, of the Yukon Territory, and in part on the slope of the river from Fort Yukon to Fort Hamlin, a distance of 190 miles. Mr. Ogilvie, after a series of synchronous barometric readings, carried on at the point where the Canadian and United States boundary line crosses the Yukon River and at Lake Laberge, deduced the slope of the Upper Yukon as 2.44 feet per mile, and the elevation of Dawson as 1,040 feet. The slope of the Yukon between Fort Yukon and Fort Hamlin is approximately .9 feet per mile. Assuming the mean of these two results as the slope between Dawson and Fort Yukon, the elevation of Fort Yukon becomes 480 feet. Vertical angles carried from this assumed elevation as a starting point check approximately with sea level at the mouth of the Kowak River.

Thirty-six azimuth observations were made at points distributed all along the route, and the magnetic declination was determined at each azimuth station.

The plane-table and stadia work was checked by 19 latitude observations, 14 of which are solar and the remaining 5 made on Polaris.

The longitude of Fort Yukon, as determined by Captain Raymond, was accepted as a starting point. The closure on Captain Beechey's position for Chamisso Island, as corrected by T. G. Gerdine, was 3½ miles long. This was distributed between extremes in proportion to the longitudinal distance.

GENERAL GEOGRAPHY.

The most important physical feature of that portion of Alaska lying north of the Yukon is a great mountain range extending from the Arctic coast just north of Kotzebue Sound east and northeast to the international boundary in the region between the Porcupine River and the Arctic Ocean. To this range, whose central portion he could see from Lookout Mountain on the middle Koyukuk, Lieutenant Allen, in 1885, applied the name Endicott Mountains. These mountains extend from the vicinity of the Mulgrave Hills east and northeast to Demarcation Point and the British Mountains in the vicinity of the international boundary.

The mountains have a north-south width of 30 or 40 miles. At their western end they are narrow and comparatively low, reaching heights of 3,000 or 4,000 feet, but near the head of the Kowak, peaks reach altitudes of 6,000 feet, and in the vicinity of the Totsenbet River portage and eastward to the boundary 7,000 feet is not unusual. The mountain belt is broader, too, toward the east, where it may have a maximum north-south extension of 100 miles. In Canadian territory it bends to the south near the Mackenzie River, and is considered a continuation of the Canadian Rockies.

Between this mountain belt and the Arctic Ocean there is a triangular area of relatively low country, with Point Barrow forming its northern angle. On its coastward side this region is a true coastal plain, and adjacent to the mountains it is a low, rolling plateau with an elevation of between 1,000 and 2,000 feet above sea level.

As might be expected, the mountain range forms a barrier between regions of strong contrast, both in meteorologic conditions and in floral and faunal life. North of it the cold Arctic storms, with snowfall and freezing temperatures, may be expected at any time throughout the year; south of it the summers are hot and bright, although short, and from two to three months of midsummer are free from snows and low temperatures. North of the range the country is timberless; south of it trees are more or less abundant in the river valleys.

Physically, the belt of country lying between the Endicott Mountains and the Yukon is much more diverse, as well as more extensive, than that to the north of the mountains. More or less isolated groups and ranges reach in exceptional cases altitudes of over 5,000 feet. Generally, however, the ridges have altitudes between 1,000 and 3,000 feet and are separated by river valleys which here and there open out into broad flats, comparable, except in extent, to the well-known basin of the Yukon, whose center is in the vicinity of the mouth of the Porcupine River.

The most important streams rise, as is to be expected, in the Endicott Mountains, which form a general divide between the Arctic drainage proper and that of Bering Sea and Kotzebue Sound. The largest of these rivers is the Koyukuk. This is about 700 miles in length and, by its numerous important northern tributaries, among which may be mentioned the Dietrich, Totsenbet, and Allen rivers, drains the southern slopes of the Endicott Mountains, between the meridians of 149° and 154° west longitude. East of the one hundred and fifty-fourth meridian the southern slopes are drained by the Chandlar and Porcupine rivers, and west of the one hundredth and forty-ninth meridian by the Kowak and its branches. The Noatak River, rising near the one hundredth and fifty-fifth meridian, in a high mountain group, whose drainage is shared by the Kowak, Alashuk, Colville, and Noatak, flows west along the sixty-eighth parallel to within 40 or 50 miles of the Arctic coast, then turns south through the range and empties into Kotzebue Sound near the entrance to Hotham Inlet. The position of the Colville on the north slope of the Endicott Range corresponds to that of the Koyukuk, opposite it, on the south slope, and its drainage basin is almost as extensive. It enters the Arctic about midway between Point Barrow and the international boundary.

East of the Colville the streams which reach the Arctic coast within United States territory are small, Turner River, perhaps 150 miles in length, being the largest known. West of the Colville, however, several streams flow northward, the Chipp, the Meade, the Otukah, and the Pitmegea being the most important.

LOCAL GEOGRAPHY AND ROUTES.

DALL RIVER.

The Dall River joins the Yukon 9 miles above Fort Hamlin, near the western edge of the great Yukon Flats, the lower 50 or 60 miles, about half the length, of Dall River lying within these, although near their western limit. The country is utterly devoid of relief and contains a great number of sloughs and ponds, many of them old and abandoned courses of the Dall and its tributaries, so that

during periods of high water the entire area is flooded and the course of the river is marked only as a lane through the spruces and willows. At such times it may be difficult to find land areas of sufficient size for camping purposes, and transportation by other means than boats is out of the question.

For about 25 miles below Dall City the river, although not in the Yukon Flats proper, wanders back and forth across a rather broad valley, bounded at some distance on either side by hills which approach the river and increase in height toward its source. Near the upper end of this stretch a branch almost equal in volume to the main stream joins the latter from the north. Dall City, so called, consists of two or three abandoned prospectors' cabins, and lies at the point where Dall River is crossed by the overland trail, at the entrance to the canyon-like upper portion of the valley. Our party did not traverse this canyon, since it is impassable for small boats, as it has a fall of nearly 1,000 feet in an air-line distance of less than 10 miles.

The general divide between the Dall River and the Koyukuk stands at between 3,000 and 3,500 feet above tide, the gap at the head of the Dall River being cut 1,500 feet below this level. The hills immediately to the north of the Dall River are broad, smooth, rounded ridges, standing above timber line, and very generally devoid of all vegetable growth except hardy lichens. An area of much more rugged forms, but standing at approximately the same elevation, lies north and west of the portage in the direction of Fish Creek and Jim River.

A conspicuous valley leads northeastward from a point north of Dall City and is probably drained by the Hosiana or Swift River, which empties into the Yukon between the Dall and the Chandlar.

KANUTI RIVER.

The Kanuti River is approximately 200 miles long, and within that distance its valley presents great physical diversity. It heads in the same mountains whose northern slopes are drained by Fish Creek and Jim River, but within a few miles of its source it enters a relatively flat basin, 9 or 10 miles long and half as wide, which contains a number of small lakes and ponds, although standing at an elevation of between 1,200 and 1,400 feet. This basin, like all similar topographic features in the north, whatever their relation to sea level, is a marsh, covered with the usual tundra growth. At its lower end, in longitude 150° 45′ west, the river enters a restricted valley, so steep walled in places as to deserve to be called a canyon and having a maximum depth of 2,000 feet. The gorge-like character prevails for about 30 miles, and through much of this portion the river can scarcely be called navigable, since it is a succession of rapids, and the channel throughout is obstructed by bowlders of all sizes. Below this stretch the valley gradually broadens, and

near the camp of July 12 is an extensive flat, which is perhaps a part of the broad basin in which the lower portion of the South Fork of the Koyukuk flows.

Within this lower basin the Kanuti River receives a large tributary from the south in the direction of the sources of the Tozi and Melozi.

About 25 miles above its mouth the river plunges into a second canyon about 10 miles long and 500 feet in depth. This is the most beautiful section of the river; the stream is swift, but free from dangerous rapids, and the bluffs of slate and sandstone rise sheer from the water to a height of several hundred feet. Ten miles above the mouth it receives the waters of the Mentanontli, descended by Lieutenant Allen in 1885 after his overland journey from the Yukon.

The hills which border this lower section of the Kanuti River and adjacent parts of the Koyukuk are seldom more than 1,500 feet in height, are not excessively steep, and are well timbered.

ROUTES VIA DALL AND KANUTI RIVERS.

The route followed by the Geological Survey party during the summer of 1901—i. e., up the Dall to Dall City, across the portage to the head of the Kanuti River, and down the latter stream to the Koyukuk—is not a practicable one for parties traveling in boats, because the portage from the Dall to the Kanuti is long (18 miles) and arduous, involving a climb of 2,500 feet, and the canyon of the Kanuti River, nearly 30 miles in length, is a succession of rapids through which boats must be lined with constant risk of loss.

A trail often followed by packers in summer leaves the Dall at its mouth, crosses the flats westward to the hills, and follows these to Dall City, whence the route coincides with the Kanuti River portage route as far as the divide at the head of the latter stream. At this point those bound for the Koyukuk turn to the north along a ridge separating the Swift River from the Kanuti River, but the trail above timber line is not recognizable. That portion of the route lying between the mouth of the Dall River and the hills is often impassable on account of high water, and pack trains may be delayed for two or three weeks waiting for the water to subside, as was the case in June, 1901. This difficulty may be avoided by landing opposite Fort Hamlin, 8 or 9 miles below the Dall River, whence high land, rising from the banks of the Yukon, can be followed directly to Dall City.

A winter route to the Koyukuk lies directly up the Dall to its source; then by a low gap at its head, which can not be reached by boats in summer because of rough water, to the upper basin of the Kanuti River. From the lower end of this basin Fish Creek is reached by another low pass and can be descended to the South Fork of the Koyukuk. The traveler over this route always is within reach of timber and the shelter and fuel which it affords.

ALLEN RIVER.

The type of topography which prevails along the lower Kanuti River and adjacent parts of the Koyukuk Valley continues north of the Koyukuk for many miles along the valley of the Allen. The lower valley of this stream, above the more extensive flats immediately adjacent to its mouth, is 5 to 10 miles wide and bordered by rounded hills, usually low, but reaching elevations of 2,000 to 2,500 feet in a group north and east of Siruk Creek.

Below the mouth of Helpmejack Creek the Allen receives no important branches. The Siruk, a small stream entering from the south, and the Sevenuka, of about equal volume, from the north, are the only tributaries worthy of mention.

Halfway between Siruk and Helpmejack creeks a low belt of country extends through from the Allen to the Kowak by way of the upper Hogatza and Norutak Lake, and is followed as a winter route by natives traveling from one stream to the other.

A short distance above Helpmejack Creek Malemut Creek enters the Allen from the east, and its valley is likewise followed by natives in their journeys from the head of the Kowak or the middle course of the Allen to the Totsenbet River, on their hunting excursions. This stream flows west along the southern base of the Endicott Mountains, and the pass at its head to the east is reported to be low.

Near the head of the Allen the natives report a pass leading to the upper Noatak, but used only in winter. It seems to be too high and too long for summer use.

Helpmejack Creek enters the Allen Valley through a canyon-like north-south valley, conspicuous for many miles below its outlet on the Allen. Farther up the valley of Helpmejack Creek joins a wider east-west valley, which extends through from the Kowak to the Allen and is occupied by the Kichaiakaka, Helpmejack Creek, and the pass between these two. This pass was crossed by Lieutenant Stoney in the winter of 1886 in his trip from Fort Cosmos to Chandlar Lake.

These passes and the valley in which they lie are, like Malemut Creek, situated along the southern edge of the Endicott Mountains, which here form a rugged tract of country 30 or 40 miles broad. One high, rough group, similar to but less elevated than the main range, lies to the south of this line and is bisected by the valley of lower Helpmejack Creek, but in general the mountains to the south are conspicuously smoother and lower than those on the north.

KOWAK RIVER.

The Kowak heads north of the sixty-seventh parallel and west of the one hundred and fifty-fourth meridian in a high group, which is reported to be the source of branches of the Allen, the Colville, and the Noatak. At the mouth of the Kichaiakaka it is 125 feet wide, with a depth of 6 or 8 feet; but a short distance above, Lieutenant Cantwell reports that it becomes very shallow, and, according to the natives, it breaks up into several branches, all of which rise within a short distance. Near the head of the river the valley is 3 miles or more in width, with comparatively level floor. It broadens somewhat below Walker Lake, but contracts again in the vicinity of the lower gorge, where its general course changes from south to west. Several lakes of importance are drained by its upper waters. Chief of these is Walker Lake, 14 miles long, but only about 2 miles broad at its lower and wider end. At its northern end it is but 1 mile in breadth, so that the lake is to be regarded as a water-filled portion of a stream valley scoured out and deepened by ice action.

The lake is bordered on both sides by precipitous mountains, which rise to heights of 3,000 or 4,000 feet. Southeast of it toward the mouth of the Reed River the country becomes broken, the hills, which are from 1,000 to 4,000 feet in height, being separated by broad passes which are often not much above the general level of the streams. Such a pass exists from Nutavukti Lake to the Reed River, and others, probably somewhat higher, are reported to exist between the latter and Walker Lake.

Nutavukti Lake is less than half as extensive as Walker Lake, and is rudely crescent shaped. Its north and south shores are formed by relatively high hills, but the valley in which it is situated extends northwest and southeast far beyond the limits of the lake. A third lake, named Norutak, somewhat less extensive than either of the two described, lies between the lower gorge of the Kowak and the head of the Hogatza. It was seen from a distance only, and it could not be measured accurately.

West of the lower gorge the Kowak Valley broadens to a width of 10 or 20 miles, and this width is maintained to about the one hundred and sixtieth meridian, where the valley suddenly contracts until it is only about 2 miles wide. From this point it gradually broadens again to the head of the delta, where it enters a great flat, extending from near the mouth of the Noatak to south of Selawik Lake.

All along its middle course the Kowak receives abundant tributaries, the most important ones flowing out of the mountain ranges to the north of the stream. Among them may be mentioned the Reed River, at whose head are the hot springs, first visited by Ensign Reed, of Lieutenant Stoney's expedition. A number of cabins

were built here by white men during the winter of 1898–99. The upper Noatak is reported to be easily reached from this point in winter, and to be navigable by small boats where first seen, although natives report that falls exist below. About 2 miles west of the Reed River, Beaver Creek, a somewhat smaller stream, enters from the north, but no other important tributaries are received until the Indian village near the camp of August 17 is reached. This village is near the mouth of the outlet of Lake Selby, a body of water probably 6 or 8 miles in length and situated 5 or 6 miles north of the Kowak. The northern end of the lake lies within the high mountains which form the valley wall. A very short portage from its head is reported by the natives to lead to Avaterat Lake, drained by Maunceluk River.

Eight or 10 miles below the outlet of Lake Selby, Pah River, the most important of the southern tributaries of the Kowak, flows in from the south. The valley of this stream is a favorite highway for the Kowak natives in their winter visits to the Koyukuk. A summer portage between the head of the Pah and a Koyukuk tributary is reported to be about 35 miles long and to lie for the greater part through marshy flats, across which travel is exceedingly difficult. Western tributaries of the Pah drain the slopes of the Sheklukshuk Range, the highest group of mountains south of the Kowak.

The Kogoluktuk River enters the Kowak from the north a few miles east of the one hundred and fifty-seventh meridian. It is one of the most important of the northern tributaries, and the pass at its head to the Noatak is reported by the natives to be one of the shortest and easiest leading to that river. Many rapids, however, make its navigation difficult. In the vicinity of Riley camp and below the Pick River, the Black River and Shingnek Creek join the main stream. They are unimportant tributaries, however, and add little to the volume of the river.

The Ambler is the most important of the branches of the Kowak. It joins the latter near the one hundred and fifty-eighth meridian, after flowing from near the Noatak Valley southward through the Schwatka Mountains to a broad east-west valley, which it crosses diagonally about 25 miles above its mouth. The principal tributary of the Ambler has been called by Lieutenant Stoney the Redstone, because of the color of the rock débris which it brings.

The Hunt, Salmon, Reed, and Squirrel rivers all flow into the lower course of the Kowak from the north, and by way of the valleys of most of these streams lie routes followed by the natives to the Noatak or its tributaries.

Below the Squirrel River the Kowak begins to separate into a number of channels which finally expand into the maze of intricate sloughs which make up the delta of the stream. The principal of the delta channels, and the one usually

followed by steamboats, is the southeastern branch, which enters Hotham Inlet at its head and near the outlet of Selawik Lake. There is, however, a shorter course, which leads to the inlet opposite Nimiuk Point. This channel also has been followed by the steamboat *John Riley*, and has in consequence been called the Riley Channel.

KOTZEBUE SOUND.

The long, slender peninsula separating Hotham Inlet from the main waters of Kotzebue Sound has but little relief; in the northern part, where it is broadest, heights of but 300 to 400 feet are reached. Long stretches of shore stand at about the level of extreme high tide, and the occasionally recurring shore bluffs of sand, clay, and frozen muds do not run generally more than 100 feet above mean tide level. Choris Peninsula, the highest point of this long spit, has its summit 360 feet above the water. Along the southern shores of Kotzebue Sound low sea cliffs and flats alternate, the latter marking the outlets of streams. Rounded ridges and hills, sometimes reaching heights of 1,200 to 1,300 feet, but usually lower, extend inland and separate the wide, flat river valleys. The Kiwalik, Swan (Kugruk), Ipnechuck, and Goodhope rivers are the principal streams entering the sound from the south. The Buckland River, larger than any of these, flows into Eschscholtz Bay from the southeast.

TABLES OF DISTANCES.

The following tables give the distances between the principal points along the route, as determined by Mr. Reaburn:

Distances between Fort Yukon and Fort Hamlin.

Locality.	Distance from Fort Yukon.	Distance from Fort Hamlin.
	Miles.	*Miles.*
Mouth of Porcupine River	9	184
Mouth of Chandlar River	24	169
Cabin on left bank of river	73	120
Mouth of Beaver Creek	108	85
Alaska Exploration Company's wood camp, No. 35, at foot of Beaver Slough	118	75
Cabin on right bank of river	163	30
Alaska Exploration Company's wood camp on left bank of river	167	26
Indian village on right bank of river	179½	13½
Mouth of Dall River	184	9
Fort Hamlin	193	.....

Distances along Dall River.

Locality.	Distance from mouth of river.	Distance from summit.
	Miles.	*Miles.*
Mouth of creek from north	55	46½
Mouth of Coal Creek	85	16½
Junction of North and West forks of Dall River	86	15½
Dall City, on West Fork of Dall River, head of canoe navigation	90	11½
Summit of portage between Dall and Kanuti rivers	101½	.....

Distances along Kanuti River.

Locality.	Distance from summit.	Distance from mouth of river.
	Miles.	*Miles.*
Head of canoe navigation	7	197
Mouth of creek from southeast, which heads in a low divide against a branch of Dall River	12	192
Lower end of big flat, where the river bends south and enters the canyons	27	177
Camp of July 6, in a prominent bend at mouth of a small creek from the west	37	167
Mouth of a good-sized creek from the east, at the head of a large flat	46	158
Mouth of a large stream from the south, in canyon south side of mountain	60	144
Mouth of a creek from the south	120	84
Indian cabins on right bank	130	74
Mouth of Mentanontli River	190	14
Mouth of Kanuti River, on the Koyukuk	204	.....

Distances along the Koyukuk.

Locality.	Distance from mouth of Kanuti River.	Distance from mouth of Allen.
	Miles.	*Miles.*
Arctic City	½	13½
Bergman	4	10
Mouth of Allen River	14	.....

Distances along Allen River and Helpmejack Creek.

Locality.	Distance from mouth of river.	Distance from summit.
	Miles.	*Miles.*
Mouth of Siruk Creek	44	59
Mouth of Helpmejack Creek	80	23
Mouth of Lake Creek, on Helpmejack Creek	90	13
Beginning of portage, at head of canoe navigation	101	2
Summit of portage	103	.....

Distances along Kichaiakaka Creek and Kowak River.

Locality.	Distance from mouth of river.	Distance from summit of portage.
	Miles.	*Miles.*
West end of portage, at head of canoe navigation on Kichaiakaka	373	3
Mouth of Kichaiakaka, on Kowak River	366	10
First rapids below mouth of Kichaiakaka	365	11
Second rapids below mouth of Kichaiakaka	362	14
Mouth of river draining Walker Lake	357	19
Head of gorge, one-half mile long	349	27
Mouth of Nutavukti River	342	34
Head of gorge, 1 mile long (rapids)	331	45
Mouth of Norutak River	329	47
Cabins on right bank of river	319	57
Mouth of Reed River	318	58
Mouth of outlet of Lake Selby	285.5	90.5
Indian village, on left bank of river	285	91
Mouth of Pah River	279	97
Mouth of Mauneluk River	265	111
Head of Big Island	255	121
Mouth of Kogoluktuk River	246	130
Foot of Big Island	242	134
Mouth of Kuiksherk River	227	149
Riley Camp	225	151
Pick River	223	153
Site of Fort Cosmos, at mouth of Cosmos Creek	217	159
Mouth of Salmon Creek	211	165
Mouth of Shingnek Creek	204.5	171.5
Mouth of Black River	201.5	174.5
Mouth of Ambler River	173	203
Mouth of Jade Creek	158	218
Mouth of Tunutuk Creek	151	225
Mouth of Hunt River	139	237

Distances along Kichaiakaka Creek and Kowak River—Continued.

Locality.	Distance from mouth of river.	Distance from summit of portage.
	Miles.	*Miles.*
Mouth of Kauvet Creek	125	251
Mouth of Kaligurichеark River	114	262
Mouth of Toolooksook River	111.5	264.5
Mouth of Salmon River	109	267
Mouth of Reed River	97	279
Mouth of Squirrel River	68	308
Mouth of Kowak River, at Hotham Inlet, directly opposite Nimiuk Point		376

Distances on Hotham Inlet from mouth of Kowak River to Quaker mission.

Locality.	Distance from mouth of Kowak.	Distance from Quaker mission.
	Miles.	*Miles.*
Nimiuk Point	4.5	23.5
Pipe Spit	19	9
Cape	23	5
Mission	28	

Distances along the shore of Kotzebue Sound from Quaker mission to Deering.

Locality.	Distance from mission.	Distance from Deering.
	Miles.	*Miles.*
Cape Blossom	11.5	93.5
South end of Choris Peninsula	55	50
Chamisso Island	58	47
Main shore (6 miles southeast from Chamisso Island)	64	41
Spafarief Bay, east shore of entrance	75	30
Spafarief Bay, west shore of entrance	79	26
Cape	86	19
Alder Creek	87	18
Hunter Creek	89	16
Camp Creek	93	12
Cape	98	7
Swan River	101	4
Mouth of Ipnichuk River	104.5	.5
Deering	105	

GENERAL GEOLOGY.[a]

METAMORPHIC COMPLEX.

GENERAL STATEMENT.

The geologists who have carried out studies in the interior of Alaska have almost without exception encountered and described near the base of the column a complex of more or less schistose sediments, sometimes associated with igneous rocks of various types and relations. These schists they have subdivided in their map work according as they were able to carry out subdivisions in the area studied. Different phases of the schists have in all cases been recognized, and where these have not been represented on the map, it has been because the exigencies of reconnaissance work are such that only those relations and characters which are exhibited immediately adjacent to the line of traverse are determinable, and these may not give the evidence necessary for definite subdivision, or, if subdivisions are made at one point, for correlation of these with others elsewhere. The great distances usually covered in such work increase the uncertainty of correlations because of the changing character of most rock formations from place to place. In a series of highly altered rocks, where fossil evidence is not obtainable, a reconnaissance map in which fine subdivisions are attempted is necessarily only lithologic.

A general classification along broad lines which can be followed with approximate correctness, also lends itself better to the work of the future, which will necessarily be closer and more exact, and in which many formations now not recognized will be distinguished and their relations determined. Logically, the earlier work should be done so that with future developments the first great groups may be subdivided rather than entirely replaced, hence it is deemed better now to draw only general boundaries and to omit such subdivisions as would inevitably be discarded.

Considerations of this sort have influenced the writer in grouping together a diverse complex of older rocks which probably include partial equivalents of Spurr's Birch Creek and Fortymile series,[b] and of Brooks's Nome, Kuzitrin and perhaps of his Kigluaik rocks.[c] Schrader's Rapids schist and Lake quartzite-schist[d] may also be represented. The rocks described here are regarded as in a general way equivalent to those described by the writer in a previous paper as the Metamorphic series.[e] They present many of the same characteristics and general features,

[a] See footnote regarding geologic map, p. 49.

[b] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, pp. 140–155.

[c] A Reconnaissance of Cape Nome and Adjacent Gold Fields of Seward Peninsula, Alaska, in 1900, pp. 27–31.

[d] Reconnaissance along Chandlar and Koyukuk rivers in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, Part II, pp. 473–475.

[e] Reconnaissance in the Norton Bay Region, Alaska, in 1900, pp. 199–204.

although exhibiting somewhat greater diversity lithologically. This is to be expected as a much more extended area has been studied this season than in 1900.

The grouping of these rocks in the present report is determined by the same conditions observed in the Seward Peninsula in 1900; namely, a general and considerable, although varying, metamorphism, which affects all the rock types, however diverse, and gives a clear basis for the separation of the group from younger unaltered or but little altered sediments and lavas which are found at widely separated points in the field.

AGE.

Overlying portions of the Metamorphic complex are recent unaltered beds with basal conglomerates derived in some cases directly from the schists, and containing no other material than that furnished by them. Some of these beds are of Tertiary age, as determined by plant remains collected in them, and others are regarded on somewhat less definite grounds as Cretaceous or at least Mesozoic. The members of the Metamorphic complex are, of course, older than these.

In his section across the Arctic Rockies, Mr. Schrader[a] found quartzites and phyllites of Carboniferous and limestones of Devonian and Silurian age. These exhibit the effects of metamorphic action, and probably are represented among the diverse beds included here.

Messrs. Brooks[b] and Collier[c] found fossils of Devonian and Silurian age in the rocks of the Nome series of Seward Peninsula. In 1900 the writer found on Seward Peninsula fossils which are Lower Mesozoic or Carboniferous. These Seward Peninsula rocks, as has been stated, are regarded as the general equivalents of those under consideration, because of their similarity in metamorphism and in relations to later sediments and lavas. Thus the evidence at hand tends to the conclusion that the rocks here considered are chiefly Paleozoic, probably ranging generally through this era; they may in some localities include Lower Mesozoic beds.

LOCALITIES AND DESCRIPTIONS.

DALL RIVER AREA.

The old rocks were first encountered along the upper Dall River, where the hills in which it heads rise from beneath the silts of the Yukon Basin. It is out of these rocks and the granitic intrusives which cut them that the broad ridges and spurs were carved from which the waters of the Dall, Swift, and Kanuti rivers, and many Koyukuk tributaries flow. The phase most commonly displayed

[a] Geological section of the Rocky Mountains in northern Alaska: Bull. Geol. Soc. America, Vol. XIII, pp. 233–252.
[b] A reconnaisance of the Cape Nome and Adjacent Gold Fields of Seward Peninsula, Alaska in 1901, p. 31.
[c] A reconnaisance of the northwest portion of Seward Peninsula: Prof. Paper U. S. Geol. Survey No. 2, pp. 21–22.

here is a fine, even-grained quartz-biotite-schist, with very fine and straight lamination—a true metamorphic rock of uncertain origin. This type makes up the great mass of the schistose rocks of this area. With the intrusives which cut it, it forms the crest of the divide between the Yukon and the Koyukuk and the higher parts of the branching spurs where these were examined. Farther down their flanks and away from the intrusive centers, the rock is oftener coarser, less quartzose, and less finely and evenly laminated. Other micas than biotite sometimes appear and by gradations schists are encountered which are clearly sediments carrying graphite and calcite. Interbedded with schists like these, 2 miles north of Dall City, are three or four bands of gray, often very coarsely crystalline limestone, standing at high angles and striking nearly east and west.

South of the flats at the head of the Kanuti River a series of dark, fine-grained slates and dark quartzites form the lower slopes of the wall of the valley.

Intrusives.—The schists are extensively cut by uniform bodies of granite-porphyry, which in some parts of the region occupy greater areas than the rocks into which they have been forced. These masses are particularly abundant north of the upper course of the Kanuti River and among the hills northwest of the eastern branch of the Dall. An area near the head of Fish Creek, although not visited, exhibits rough topographic forms which are presumably to be ascribed to these resistant intrusive masses.

Near the camp of June 24 on the Dall River, granites which are not porphyritic and not schistose, though deeply weathered, outcrop along the stream section, and are regarded as intrusive in the schists, although the contact is not shown. On the hill slopes to the north occasional narrow and compact acid dikes are exhibited. These are regarded as offshoots from the main intrusive mass.

In addition to these unaltered intrusives, gneissoid porphyritic rocks of granitic and dioritic composition occur in the schists. Sometimes the crushing has gone so far as to suggest that some of the biotite-schists may themselves be derived from igneous rocks of like character, but as no instance was observed in which the distinction could not be clearly made, this suggestion remains unproved. It is true, however, that the intrusion began before the metamorphic action had ceased, so that the earlier intrusives were greatly affected by it.

KOWAK AREA.

The second group of metamorphic rocks was first seen a few miles above the mouth of Helpmejack Creek, and they were encountered at intervals all along the Kowak Valley and Kotzebue Sound.

The hills in which the lower course of Helpmejack Creek is cut are made up of a gray or green compact, schistose quartzite, with occasional calcite grains;

cut by intrusive greenstone masses which are themselves much altered and have been rendered schistose. Sufficient of their original structure, however, remains to determine them as diabases.

The quartzites overlie interbedded graphitic and chloritic schists, likewise containing basic intrusive masses, greatly altered. The east-west valley in which Kowak Pass lies seems to be cut along the strike of these softer beds, whose presence may have been a determining element in locating this wide depression.

North of the portage, the immediately adjacent mountain group is made up of interbedded crystalline limestones and gray schists, the latter often very graphitic and siliceous. One bed of limestone, 200 feet in thickness, is conspicuous, and the schists for several hundred feet above it contain narrower interbedded calcareous bands.

Along the southwest shore and the islands of Walker Lake, west of the last-described area, and having the same general strike, are lustrous muscovite-schists, quartz-calcite-schists, and massive crystalline limestones. On the shore opposite, 2,000 feet above the level of the lake, narrow belts of limestone interbedded with the schists form conspicuous white bands encircling the mountain.

Below and for a short distance above the outlet of Walker Lake the Kowak crosses a belt of black slates, usually clean, smooth, and easily cleaved, but also exhibiting pencil-slate aspects due to the development of two approximately equal cleavages at right angles to each other. These slates, like the schists to the north, more usually exhibit east-west strikes and southern dips, although local cross folds and fractures occur, with resulting confused attitudes.

Among the beds outcropping along the shores of Lake Selby, and assigned to this series, are a number of greenstones of various types. More generally they are highly schistose and appear in one instance at least to be derived from the alteration of a fragmental volcanic rock. The alteration usually has gone so far that very little can be said about the original character of the rock. One specimen examined was found to be composed almost exclusively of finely granular epidote.

Above the mouth of the Kogoluktuk the Kowak swings against the north wall of its valley, and the rocks here exposed are green quartzose, micaceous, and chloritic schists. Quartz occurs as grains or lenses, from microscopic dimensions to bodies some feet in greatest diameter, and constitutes a very large percentage of the rock mass.

Near the head of Shingnek Creek, north of the range immediately adjacent to the Kowak Valley, Mr. L. M. Prindle reports limestones, mica-schists, and serpentines, and still farther to the north rugged ranges of schistose rocks. West of the lower course of the Ambler lies a high group called by Lieutenants Stoney and Cantwell the Jade Mountains, because of the occurrence of jade along their southern

A. UPPER KOWAK 1 MILE BELOW MOUTH OF KICHAIAKAKA CREEK.

In the background are mountains of schist.

B. SLATY ASPECT OF BERGMAN SERIES IN LOWER GORGE OF KOWAK RIVER.

flank. Both of these explorers visited this group, and in their search for the jade made rather extensive collections. Among the rock types brought back, Dr. George P. Merrill[a] describes serpentines and green quartzites, and the same author, in collaboration with Dr. F. W. Clarke,[b] gives detailed descriptions of several varieties of jade.

Near the eastern end of the same mountain group there is an extensive exposure of a rock which is light gray in fresh fracture, but a deep rusty-red in its usual field aspects. It proves to be composed of quartz and magnesite in approximately equal amounts. A small quantity of iron is also present, probably as a carbonate, and to this is due the characteristic color of the weathered rock.

Just above the mouth of the Squirrel River is a greenstone which consists principally of quartz, chlorite, and calcite. It is probably a greatly altered intrusive member of the schists. In the same neighborhood, a short distance back from the river, thin-bedded limestones outcrop, and these are succeeded toward the west by a rock of granitic composition, but with its component minerals much fractured and strained, so that the rock may now be regarded as a true schist, undoubtedly originally an acid intrusive. Highly garnetiferous beds were examined along the river bank in the neighborhood of the camp of August 29. Below the mouth of the Squirrel River gray crystalline limestones and clear white marbles interbedded with micaceous schists form the river bank for some distance above the delta.

KOTZEBUE SOUND AREA.

The rocks of Choris Peninsula are all highly schistose and exhibit a wide range in mineralogic composition. Schistose limestones, graphitic schists, often highly garnetiferous, and some amphibole-bearing schists outcrop here. Chamisso and Puffin islands are carved from rocks of gneissoid granite.

On the mainland, east of Chamisso Island, a quartzose graphitic schist, striking about parallel to the shore line, forms most of the rock bluffs south to the flats about Spafarief Bay. Its continuity is interrupted, however, by masses of greenstone which are regarded as altered basic igneous bodies.

The south shore of Kotzebue Sound as far west as the mining village of Deering is a succession of headlands and embayments with almost continuous exposures of members of this series. Micaceous and graphitic schists are most extensively represented, but feldspathic varieties are not uncommon, and about half a mile south of Alder Creek, associated with an impure limestone, are bodies of amphibolite-schists and serpentines.

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[a] Science, Vol. V, 1885, p. 209.

[b] Proc. U. S. Nat. Mus., Vol. XI, 1888, pp. 115–130.

The same general series presumably continues westward along the shores of Goodhope Bay to Rex Creek, where it was reported by Beechey and by prospectors to be succeeded by recent volcanics.

STRUCTURE.

But little definite structural evidence was collected in the region of the Dall River portage. The schists, where so extensively intruded by the porphyries, are generally nearly vertical, but exhibit very confused strikes. Near the southern edge of this area, where interbedded limestones gave datum planes from which to determine attitude, the schistosity and bedding were found to correspond. Here the dips were to the south at rather high angles, with strikes varying somewhat, but generally east and west or a few degrees north or south of these directions. The northern edge of this field was not reached nor anywhere closely approached, but the fact that the majority of the strikes and dips recorded near the southern margin are to the south and the greater proportion of the porphyritic intrusives occur some distance north of the margin nearer the center of the mass, suggests that the general structure may be anticlinal.

The schists where examined along and north of the Kowak almost universally exhibit east-west or nearly east-west strikes parallel to the Endicott Mountains, whose southern flanks they form here. Their dips are, as generally, southward, away from the mountains. They pass under the silts, gravels, and recent deposits of the Kowak Valley, and probably do not rise to the surface again on the south side of the mountains except at one or two points within the drainage basin of the Kowak. Hotham Peak and its immediate vicinity and the Sheklukshuk Range, although not examined, show topographic forms which are characteristic of the schistose series in other localities, and the streams draining them carry schistose pebbles, so that limited areas in the immediate vicinity of these mountains are probably made up of these older rocks. Hence the Kowak occupies a great strike valley, and probably portions of that valley are synclinal.

So closely do the measured strikes in the schists conform to the direction of the valley walls at each particular point measured that it is suggested that the minor irregularities of the valley (its local variations from an east-west direction) may correspond to and be dependent upon equivalent variations in the trend of the schistose series.

VEINS.

Along the Dall River portage the mass of old rocks is very siliceous, and blebs of pure white quartz, often of large size, occur. A lens exposed along the trail above Dall City is 10 feet in thickness and 40 or 50 feet long. It displays unbroken interlocking quartz crystals and rhombic cavities from which calcite has been dissolved, but no other mineralization is in evidence at the surface. Its

unfractured character and the corrugations along its margin, corresponding to the crinkling in the schist which formed the walls of the cavity at the time of its precipitation, indicate that it is of later date than the crinkling and the crushing forces to which the general metamorphism is due. These occasional occurrences of large bodies in the Dall River area are rather exceptional, and the majority of the veins are of minor importance and appear as narrow stringers.

The quartzose schist of upper Helpmejack Creek contains stringers and a few heavier veins. Pegmatite also was observed here. In the neighborhood of the Kowak portage the schists do not carry continuous veins, but lenticular bodies 18 inches in greatest dimension were sometimes seen. Some of the quartz in these lenses is clear and glassy.

The black-slate phase above and below the outlet of Walker Lake and the schists below Kichaiakaka Creek are filled with fine but nonpersistent veinlets, usually parallel to the cleavage of the slates. The rocks of the series most extensively affected by quartz fillings are those on the north bank of the river in the vicinity of Kalla. Lenses and knots here make up probably no less than 50 per cent of the rock mass in many instances. Extensive regular and persistent veins, however, were not observed.

The Kotzebue Sound occurrences carry quartz veinlets, and occasional blocks of large size on the beach indicate the presence of considerable masses. Many of the tiny stringers here are found to be involved in the folds and intricate crinkling of the schists. This condition, while not universal, is the usual one in these rocks, so that much the greater part of the quartz filling has occurred early in their history and previous to the latest deformation.

KANUTI SERIES.

LOCALITIES AND DESCRIPTIONS.

About 27 miles by river west of the portage from the head of the Dall, the Kanuti River enters a canyon nearly 30 miles long, cut in rocks of a type entirely different from any encountered in extensive bodies elsewhere. Very compact greenstones of doubtful origin and some fine-grained pyroclastics occur at the head of the canyon. These are intruded by dioritic rocks composed of green hornblende and plagioclase, and are succeeded downstream by compact and vesicular basalts and detrital rocks in the form of volcanic tuffs and hornstones veined with quartz. The hornstone resembles some phases of the schistose series, but its indurated character is regarded as the result of intrusive masses in its immediate vicinity.

The greater and much the most conspicuous portion of the Kanuti series is made up of intrusive rocks. In certain prominent red hills near the camp

of July 6 there are masses of ultrabasic rock often much altered to serpentine, but identifiable in particular cases as pyroxenite and hornblendite. Their dark-red color when weathered is due to the iron, which they contain in sufficient amounts to cause a disturbance of the magnetic needle in their vicinity.

Greenstones and intrusive bodies, the latter belonging to dioritic or gabbroic magmas, continue to form the valley walls downstream from the occurrence just described until the river passes out into the lower flats, except for some bluffs along the right bank of the river in the vicinity of the camp of July 8, where more recent lavas and tuffs occur.

An isolated hill, 800 to 900 feet high, around whose southern base the river flows just before entering the flats, is the last outcrop examined which belongs to the rocks of this type. It proves to be a mass of serpentine with much later intruded diabase.

Two or three belts of granitic rock, apparently occurring as later intrusives, cut the series at adjacent points along the river.

INTERRELATIONS.

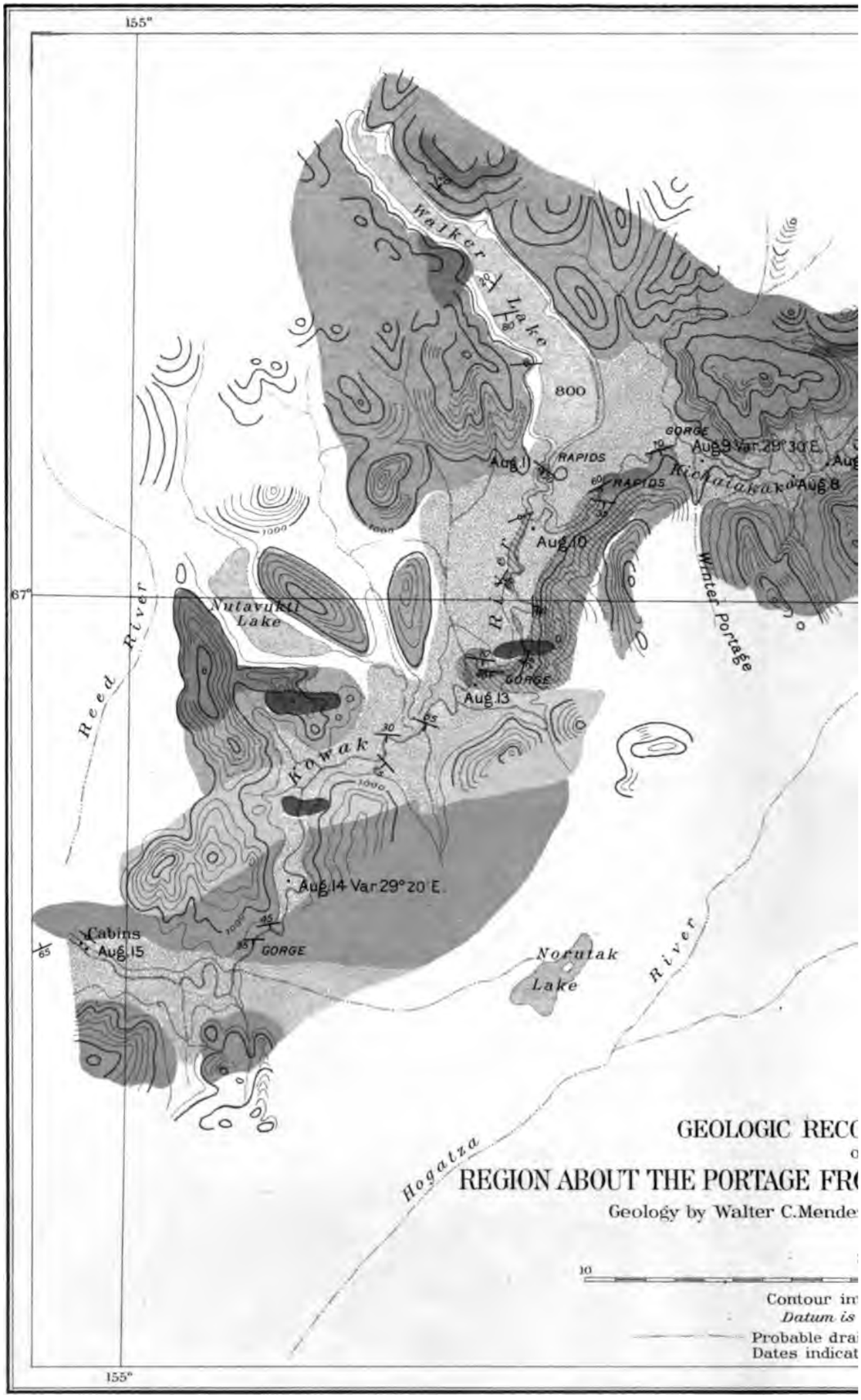
The rocks which have been grouped together here as the Kanuti series are very diverse in mode of occurrence, but with the exception of the hornstones described above they are generally basic igneous rocks or their pyroclastic equivalents. The oldest members are the greenstones and hornstones, which exhibit considerable mechanical alteration. Younger than these are the massive gabbroic rocks (and the serpentines derived from them), which are regarded as intrusive in the bedded greenstone members, while the most recent rocks of the series are the basalts, basaltic tuffs, and diabases, the latter intrusive in certain instances in the serpentines.

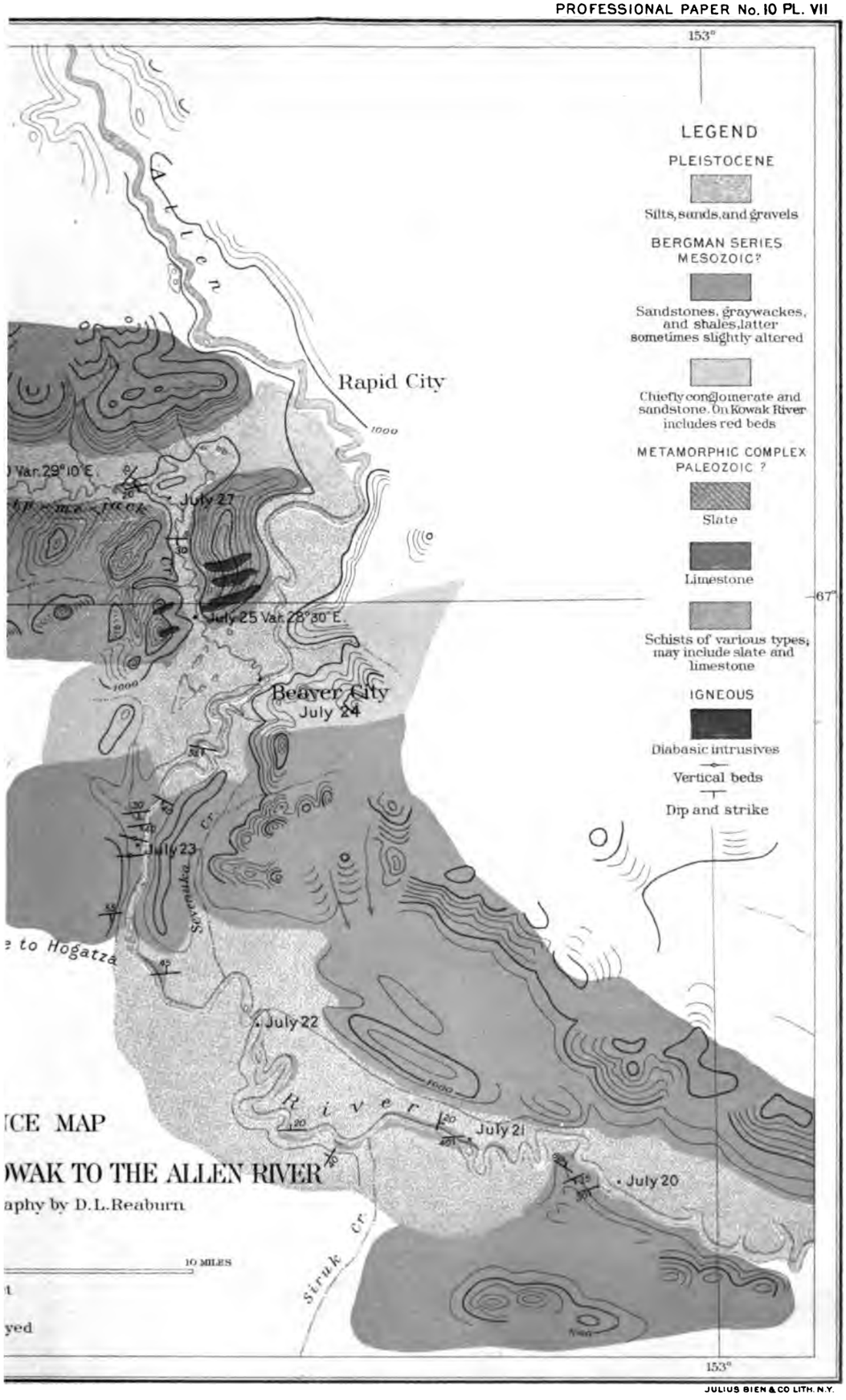
AGE AND EQUIVALENTS.

The entire series is regarded chiefly upon the basis of less extensive mechanical alteration as younger than that phase of the schistose beds studied along the Dall River portage. These are regarded as among the oldest of the schistose series, being probably of early Paleozoic age. The earlier of the Kanuti rocks may then be considered as Middle Paleozoic. Mr. Spurr's Rampart series,[a] consisting of diabases, which he regards as flows, and associated sediments and tufas, outcrops along the Yukon 50 miles southeast of the occurrences on the Kanuti River. Except that no equivalents of the massive gabbroic rocks of the Kanuti River are described along the Yukon, the resemblance between the occurrences is sufficiently close to suggest that they represent the same conditions and belong to the same period.

[a] Geology of the Yukon district, Alaska; Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 155–169.

U. S. GEOLOGICAL SURVEY





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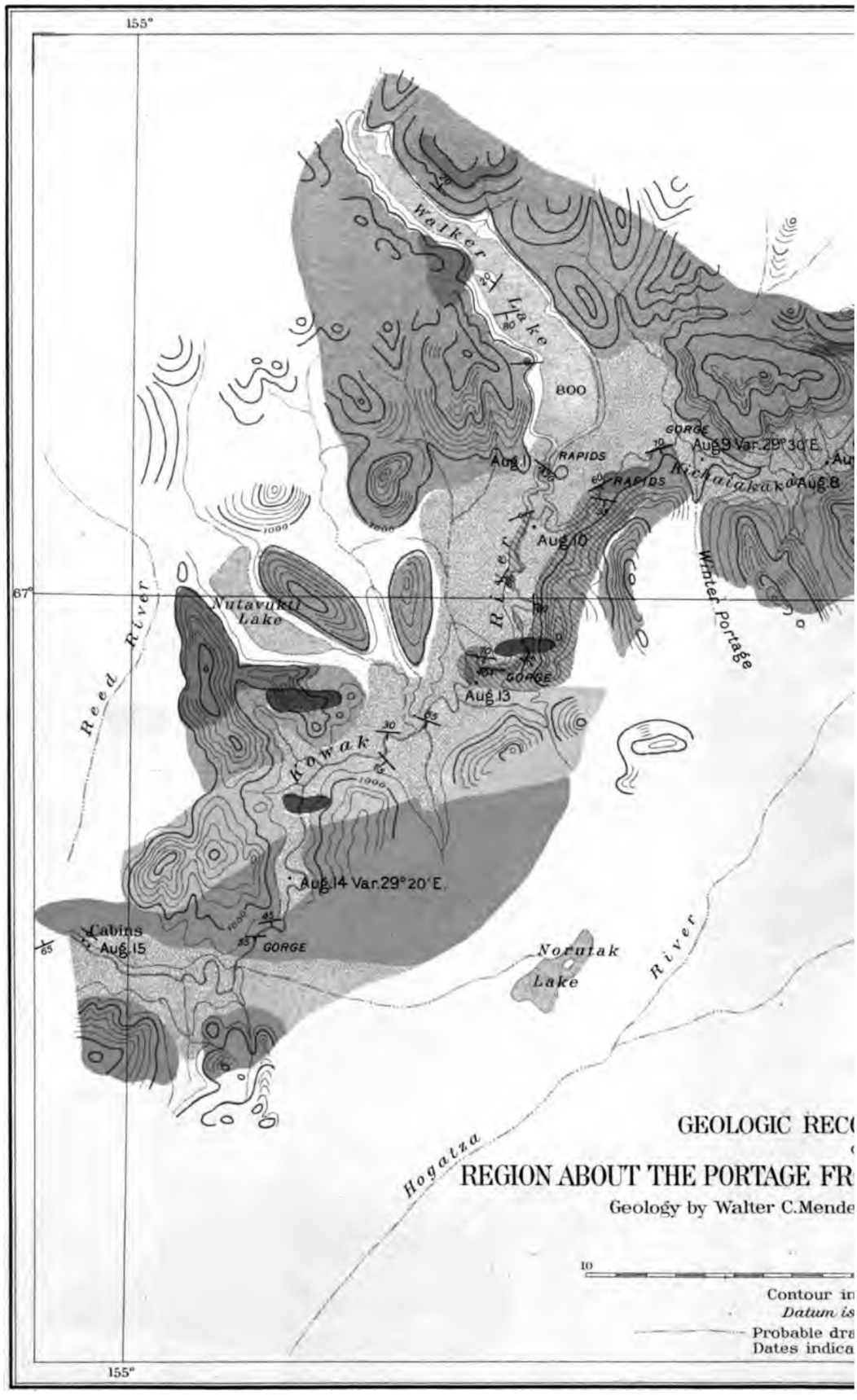

BERGMAN SERIES.

LOCALITIES AND DESCRIPTIONS.

Twenty-five miles above its mouth the valley of the Kanuti River closes in abruptly and the stream enters a narrow defile with walls several hundred feet high, which are composed of folded sandstone; fine conglomerates; and dark, sandy shales. Below Mentanontli Creek outcrops of these rocks are less frequent, but the hills back from the river on either side are found to be made up of sediments of the same general character. They are well shown along the Koyukuk between Arctic City and Bergman, although more arenaceous here than in some localities, and they extend up the Allen to beyond the mouth of Helpmejack Creek. Usually the sandstones and shales are associated in thin, sharply defined alternating bands, but occasionally the sandstones disappear and broad belts of shale many hundred feet in thickness are found.

Passing northward up the Allen thin conglomerate beds begin to appear with pebbles of black and green flint and occasionally of quartz. The shales decrease in amount and become somewhat more fissile as the sandstones are replaced by the conglomerates.

In the vicinity of Beaver City outcrops of the basal portion of the formation consist almost exclusively of conglomerate, which is not usually coarse, and contains pebbles of diversified types derived from the older rocks to the north. The conglomerate lies nearly horizontal and extends eastward to Totsenbet River, where it has been reported by Mr. Schrader.

On the Kowak, a few miles above the outlet of Lake Nutavukti, conglomerates are exposed which, although exhibiting some variations from the type, are regarded as belonging to the Bergman series. The conglomeratic beds are here interbedded with red and green shales, and a considerable body of soft red sandstones occurs in one locality. In the conglomerate occur pebbles of slate, greenstone, and other types, which are recognized as derived from the older rocks to the north.

Through the mile gorge, a short distance above the outlet of Norutak Lake, the Kowak flows along the strike of a slaty phase of the Bergman, which is very similar lithologically to a belt crossed along the Allen nearly due east of here. The slates in the canyon of the Kowak carry small limestone lenses and are cut by narrow quartz stringers. They have been only very slightly metamorphosed.

Below the gorge the river enters a broad, filled valley with no rock exposures until the mouth of the Reed River is reached. Here slaty shales, similar to those in the gorge above, are found in outcrop and exhibit a northerly dip, while those in the gorge dip toward the south. Five or 6 miles farther downstream, soft, green, fractured sandstones and graywackes, frequently weathering red, are encountered.

A short distance above the mouth of Pah River the hills south of the Kowak are found to be composed of these same Bergman beds. The shales predominate here, and the topographic forms to which they give rise extend westward to the head of the Kuikcherk River and eastward as far as can be seen.

STRUCTURE.

The beds of the Bergman series are everywhere folded to a greater or less degree, the amount being dependent on the resistant power of a particular portion of the mass as well as on its situation relative to the stresses which have brought about the folding. In the first exposures observed along the Kanuti River, 20 or 25 miles above its mouth, the interbedded sandstones and shales are thrown into close folds, anticlines and synclines succeeding one another rapidly with maximum dips of 65°. No faults were observed. Along the Koyukuk, between Arctic City and Bergman, the beds, here more arenaceous, are likewise folded. A fault of unknown throw which crosses the river here has been figured by Mr. Schrader.[a] Along the Allen north of the Koyukuk the beds generally dip toward the south at angles of from 20° to 60°, only occasionally and for short distances exhibiting dips to the north.

Near the northern limit of the formation the basal conglomerates form a broad belt, and where exposed in the neighborhood of Beaver City are horizontal or dip to the south at low angles. Corresponding outcrops of conglomerate along the upper Kowak show higher dips, but in the same general direction.

The black shales in the lower gorge of the Kowak dip to the south at angles varying from 45° to 65°, and the similar and probably equivalent beds at the mouth of the Reed River have northerly dips, as do those just above the Pah. Some faulting has taken place in the sandstones below Beaver Creek, but it is probably not extensive.

To summarize, it may be said that the structure of the Bergman series is complex, involving abundant open folds and some faults of unknown extent, but that in a broad way it forms a synclinorium with bounding walls of older rocks outcropping toward the northwest and the southeast.

AGE.

The beds of the series were closely scanned by the writer over a broad area and have been carefully studied for two seasons by Mr. Schrader, but as yet no determinable fossils have been found in them. Indistinct and fragmental plant remains occur in places, and fragments of coaly material were noted in the conglomerate at one locality. The conglomerate forming the basal member of the series is derived

[a] Reconnaissance along Chandlar and Koyukuk rivers, Alaska, in 1899: Twenty-first Annual Rept. U. S. Geol. Survey, Part II, p. 469.

principally from the schists which have been described, hence the beds are later than these. Usually they are wholly unmetamorphosed, but the beginnings of metamorphism appear in some of the shaly phases along the middle Allen and in the gorge of the Kowak. These beds may eventually have to be separated from the Bergman series, but sufficient evidence was not gathered this season for such a separation, hence they are included with the entirely unaltered rocks. The induration is generally greater than that of the lignite-bearing Tertiary beds of Dall River and those of the lower Kowak, although folding is but little if any more complex. From these general characters, the beds are to be regarded as pre-Miocene, and since the older schists probably include members extending well up in the Paleozoic, we may assign the Bergman to the Mesozoic, pending the finding of more definite evidence.

KENAI SERIES.

LOCALITIES AND DESCRIPTIONS.

About a mile above the mouth of Coal Creek, a western tributary of the Upper Dall, there occurs an outcrop of soft gray, buff, or black shales, standing at an angle of about 30° and associated with a heavy bed of lignitic coal and bone. A short distance upstream from the mouth of Coal Creek, the Dall River receives a tributary from the north which carries lignite fragments, proving the occurrence of lignite-bearing beds somewhere within its drainage basin. No fossils were found in any of these Dall River beds, but because of the character of the lignite which occurs in them, and their own lithologic resemblance to well-determined strata in other parts of the territory, they are assigned with considerable confidence to the Kenai group.

Along the lower course of the Ambler, outcrops were examined which consisted of a series of conglomerates, soft, cross-bedded sandstones, and shales, which were often carbonaceous and carried obscure remains of plant stems. Some phases of the conglomerates are made up wholly of material derived directly from the mica-schists and but little sorted. White vein quartz, somewhat rounded, furnishes most of the material for the pebbles, which are embedded in a matrix, consisting chiefly of fine muscovite and chlorite foils. These beds make up the low hills between the lower Redstone and the Ambler and between the latter stream and the Kowak. Similar beds, associated with limestone, are reported by Mr. Prindle along the middle course of Shingnek Creek.

Just below the mouth of the Hunt River a hard quartz conglomerate containing coal fragments was found in place, and prospectors report similar beds as forming bluffs for several miles along the lower course of the Hunt River.

The most extensive exposures of these beds along the Kowak are found in outcrops along both banks for 8 or 10 miles below the mouth of the Reed River. Here a succession of conglomerate layers, with pebbles of quartz, mica-schist,

limestone, and serpentine embedded in a micaceous matrix, alternate with less resistant and hence less well-exposed beds. The individual conglomerate plates vary from 10 to 200 feet in thickness, but are quite uniform in character. The softer beds separating them are sandstones, shales, fire clays, and coals.

STRUCTURE.

These rocks are everywhere thrown into folds, whose details are not generally determinable from the evidence gathered. Faults were not observed. The rather uniform southerly dips which generally affect the older beds to the east are absent, the structures being more local in character.

AGE.

A few fossil plants were collected below the mouth of the Reed River and submitted to Dr. F. H. Knowlton for determination. He says, "This collection consists of five small specimens, the matrix being grayish, fine-grained, very hard sandstone. The plant remains are not retained with great fidelity, but fortunately all are determinable. Four species are represented, as follows: *Ginkgo* sp. probably *G. adiantoides* (Unger) Heer, *Taxodium distichum miocenum* Heer, *Taxodium tinajorum* Heer, *Populus arctica* Heer. With so few species as a basis for comparison, it is not possible to speak very dogmatically as to their probable age, but all things considered, I should incline to refer them to the so-called Arctic Miocene, which is now generally regarded as belonging, really, to the Upper Eocene."

This identification assigns these beds with much probability to the Kenai group, where they were placed on more general grounds by Dall and Harris[a] in 1892. The Ambler River occurrences are assigned to the same period because of lithologic resemblances, indistinct vegetable remains, and associated carbonaceous matter.

LAVAS.

Basalt.—Along the middle Kanuti River, in the vicinity of the camp of July 9, horizontally bedded vesicular olivine-basalts form bluffs 50 to 75 feet high on the north bank of the river, and similar bluffs south of the valley are probably due to the same formation.

South of Goodhope Bay, Beechey reported olivine-basalts, and the accounts of prospectors tend to confirm the presence of a recent lava here. Somewhat farther south, the writer[b] in 1900 found extensive sheets of basaltic lavas in the valley of the Koyuk River, and Mr. Collier[c] in 1901 found similar areas in the valley of the

[a] Bull. U. S. Geol. Survey No. 84, p. 248.
[b] Reconnaissance in the Norton Bay Region, Alaska, in 1900, p. 206.
[c] A reconnaissance of the northwest portion of the Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, p. 31.

A. OUTCROP OF TERTIARY (KENAI) SEDIMENT, COAL CREEK.

B RAPIDS IN OUTLET OF WALKER LAKE.

The stream here for a few hundred yards cuts bed rock; throughout the remainder of its course it has gravel banks.

at the lower end. They have been deposited by the stream while flowing at its present level, since the silts do not in any observed instance extend above the flood plain stage of the river. The lower basin of the Kanuti River is more extensive, and the deposits more complex. The flats begin about 140 miles above the mouth of the river and extend 100 miles downstream. At first they occupy a valley about 4 or 5 miles wide, but near the mouth of a large tributary from the south this valley and the deposits which fill it expand to a width of 20 to 25 miles. Usually the silts stand but a few feet above the water level, but near the center of this basin there occur several groups of hills composed of silt and sand, which rise from 100 to 200 feet higher. They are remnants of an earlier deeper filling, the rest of which has been removed by erosion.

Allen River.—The lower Allen Valley and the immediately adjacent parts of the Koyukuk Valley are filled with silts and gravels, and these extend up the Allen, increasing in coarseness but decreasing in lateral extent as the valley narrows, until they merge with comparatively coarse glacial deposits in the vicinity of Helpmejack Creek. The limits of glacial activity within the Allen Valley can not be accurately determined from the data at hand, but the character of the gravels is such that they may all be regarded as water-transported and sorted glacial débris.

Kowak River.—Similar material is abundant about the outlet of Walker Lake and is spread over the floor of the Kowak Valley as far down as the lower gorge of that stream. The truly glacial filling, however, is probably best developed within the valley drained by Helpmejack and Kichaiakaka creeks, along which the portage from the Kowak to the Allen lies.

Below the gorge of the Kowak the glacial aspect of the gravels and sands gradually fades, and the entire middle stretch of the river, from the gorge to the mouth of the lower Reed River, is filled by a mass of unconsolidated clays, silts, and sands, which, whether originally fluvial or glacial, can not now be distinguished from such deposits as occupy the Yukon Flats. The "Kowak clays," described by Cantwell from an outcrop just above the mouth of Jade Creek, and the subject of a notice by Dall and Harris, are perhaps the best exposure of the finer phase of these beds, although cut banks of similar material are not at all unusual in this section. The clays here occupy the same relation to the stream as do the sands and gravels farther up the valley, and are to be regarded as but a downstream and consequently finer representative of these. Both the silts of the middle section and the coarser deposits of the upper form bluffs which sometimes rise to heights of 150 feet above the water level.

The valley of the Kowak is comparatively narrow between the mouths of the Reed and Squirrel rivers, being here but 2 to 4 miles across as compared with

four or five times this width above, but below the Squirrel River the expansion of the delta begins, and where the waters of the various sloughs and channels enter Hotham Inlet the width along an approximately north-south line is 26 to 27 miles. The delta deposits are frozen muds and vegetable accumulations, with occasional masses of quite clear ice. Many writers since Kotzebue have discussed the origin of these ice cliffs, but the explanation given by Mr. L. M. Turner,[a] Messrs. E. W. Nelson and C. L. Hooper,[b] and Prof. I. C. Russell[c] seems to be entirely adequate. It is that many of the numerous lakelets scattered about over the tundra are gradually buried by the advance of their mossy borders toward the center. After their burial they are frozen, as is the entire tundra, a few inches below its surface and are later revealed by lateral river cutting, as in the Kowak delta, or by the work of waves, as at Elephant Point, and appear as masses of comparatively clear ice in the general deposit of frozen mud, sands, and vegetable matter.

Kotzebue Sound.—All of the peninsula which separates Hotham Inlet and Selawik Lake from Kotzebue Sound and its waters, with the exception of the extreme southwestern point (where members of the schistose series outcrop in Choris Peninsula), is made up of Pleistocene silts, clays, and embedded ice. Its outline and topography suggest that shoals which have formed off the mouths of the Noatak, the Kowak, the Selawik, and the Buckland have been raised into islands by slight local elevations, and that these islands have afterwards been tied into one long peninsula by the action of winds, waves, and currents.

Elephant Point is a famous locality for the bones of extinct and living species of mammals and has been visited by Kotzebue, Beechey, Nelson, Dall, and others. At Cape Blossom similar remains are found, and Cantwell reports tusks of the mammoth on the Kowak below the Ambler. Mammoth bones were observed this year near the head of Hotham Inlet, and they may be looked for anywhere in the frozen clays and silts of this region where there are exposures. For a fuller discussion of these fossils and of the formation in which they are found the reader is referred to Dall and Harris.[d]

GLACIATION.

That part of the region between the Yukon and the Koyukuk which was visited shows no evidences of glacial action and exhibits abundant phenomena to prove that there has been no such action there within geologically recent times. The slopes bordering the valleys have not been cleared of their mantle of débris; no rock

[a] Contributions to the Natural History of Alaska, Signal Office, Washington, 1886.
[b] Report of the cruise of the U. S. Revenue steamer *Thomas Corwin* in the Arctic Ocean, 1881,
[c] Surface geology of Alaska: Bull. Geol. Soc. Am., Vol. I, 1889, p, 128.
[d] Correlation papers. Neocene: Bull. U. S. Geol. Survey No. 84, p. 260 et seq.

scorings are to be seen; the recent deposits along the middle and lower courses of the Dall River are stream-laid silts, and the sands and gravels contain, so far as examined, no bowlder clays. The mountainous country about the head of the Kanuti, Dall, and Swift rivers and the various southern tributaries of the Koyukuk is characteristically rough in its higher portions, without evidence of the smoothing action of a general ice sheet, while in the upper Kanuti River Valley the dikes of granite-porphyry which intrude the slates and schists of the region form rough minor ridges near the present stream level and exhibit disintegration bowlders and other undisturbed forms due to weathering. The canyon below the upper basin of the river is likewise free from evidence of ice work, the disintegration mantle being usually present where the grade of the valley walls is such that it may be expected.

North from the Koyukuk, however, evidences of ice work begin to appear. The isolated mountain mass lying between Helpmejack Creek and the Alashuk River has suggestively smooth forms, and there are scattered about on its summit a few rounded quartz and quartzite pebbles. No definite striations and no considerable glacial deposits were noticed, but, standing as it does near the junction of the three valleys of the upper Helpmejack, the upper Alashuk, and Malemut creeks, it is conceivable that the ice which occupied these valleys may have temporarily capped this knob, although its general level was much lower.

More definite evidence is obtained in the neighborhood of the portage to the Kowak and about Walker Lake. Distinctly striated pebbles occur along upper Kichaiakaka Creek, and the confused topographic forms of the gravel fillings of this valley and its continuation westward across the portage to the Kowak immediately suggest ice action. Along Helpmejack Creek and the middle Allen drainage changes have taken place which are best explained by glacial action. The direct topographic continuation of the upper Helpmejack Creek Valley is eastward into the Allen by the pass which leads to the latter stream in the vicinity of Rapid City, but Helpmejack Creek at present leaves this broad, open way, turns to the south at right angles to its logical course, and reaches the Allen at Beaver City. Such a course probably was originally a spillway for glacial waters, and in it Helpmejack Creek became intrenched while the more northerly outlet was still occupied by ice. Upper Helpmejack Creek occupies a filled valley, but not a systematically filled one. The valley is occupied by incompetent meandering streams and numerous small ponds at varying elevations. Its ridges and terraces, while of waterworn sands and gravel, so far as examined, are at no constant elevation and bear no obvious relation to each other. In short, the topography and stream alignments are of the confused type which results from ice work, and

are in strong contrast to the more regular types which are due to normal stream growth.

The filling of the valley of Kichaiakaka Creek, is sufficiently deep to effectually conceal bed rock except at one doubtful point, and is made up of fine gravels and sands, including schist, quartz, and granitic pebbles, practically all local rocks, but no clays nor angular material, so far as observed. The area is but imperfectly drained; kettles without surface outlets, long, low ridges, transverse to the valley, and irregular gravel hummocks being typical forms.

On the islands in Walker Lake are exhibited the only roche moutonnée surfaces that were observed during the summer. These forms were revealed at first only near water level, where the bed rock was free from its usual vegetable cover, and their occurrence here suggested that the polishing might be due to the action of lake ice in the spring and fall, when under the influence of strong winds, but a close examination proved the action to have been regular and constant in direction, and that direction, as indicated by the well-marked grooves parallel in places to the shores of the islands, was at right angles to the lines along which lake ice would usually work. The striæ on these polished surfaces are generally parallel to the long axis of the lake, and, although well-marked stoss and lee sides do not exist, there can be no doubt that the glacier which occupied the lake basin flowed down from the high mountains northwest of the lake toward the valley of the Kowak.

The stream which drains Walker Lake flows between gravel banks except at one point midway of its course, where it cuts a bed-rock barrier and becomes for a few hundred feet a wild rapid. The low gravel hills about the lower end of the lake exhibit the same tumbled and irregular arrangement which marks those of the Kichaiakaka. Angular forms such as are produced by ordinary subaërial agencies mark the higher slopes bordering the lake, and a general rounding without evidence of violent action characterizes the lower slopes for at most a distance of but a few hundred feet above the present water level, so that the ice stream which filled the valley now occupied by the waters of the lake seems not to have been a deep one. The present outlet of the lake probably marks approximately the southern limit of the glacier at its principal stage of advance, and the materials discharged at its front, sorted and worn by the waters flowing from it, built up the valley beyond and remained as a dam after the retreat of the ice tongue. Along the eastern shore and near the southern end of the lake, exists a mass of angular material, probably representing a moraine built by an ice stream from Walker Lake or the upper Kowak.

Just above the mouth of the Reed River, at the junction of its valley with

that of the Kowak, is a low hill made up of the Bergman conglomerates, and leading out from its foot toward the mouth of the Reed River is a long train of angular rubble composed of schistose rocks. Evidently this is the moraine of an ice stream which occupied the valley of the Reed River and headed back among the altered rocks of its upper course, for material of the type represented in the moraine does not outcrop in this vicinity.

At the lower end of Lake Selby the gravel hills which dam it exhibit the general irregularities which characterize those of the Kichaiakaka Basin, and small undrained tracts are often inclosed in the encircling mounds. Along the west shore of the southern end of the lake three or four gravel ridges show a rough parallelism, all of them making a large angle with the axis of the lake. They are of waterworn material and belong rather to the esker than to the morainal type.

About 2 miles above the mouth of the Ambler River on its left bank occurs a deposit of blue bowlder clay 25 feet in thickness. Blocks and pebbles of dark crystalline limestone, much greenstone, and relatively small amounts of conglomerate and sandstone are scattered through the clay, and these bowlders are sometimes subangular and finely striated. The rocks of the lower course of the Ambler are sandstones and conglomerates, so that the greater part of the coarser material in the clay has been transported at least some miles. Overlying the clay are deposits about 100 feet in thickness of irregularly stratified yellow sands and clays without coarse material. The lower portion of this deposit at least is to be regarded as a true ground moraine, thus proving the extension of the Ambler Valley glacier to beyond this point.

The high mountain group separating the headwaters of the Noatak from those of the Kowak and extending thence eastward and westward was a center from which valley glaciers radiated along the principal drainage lines. These valley glaciers have extended down the northern tributaries of the Kowak at least to the main east-west valley of that stream, and have furnished much of the material with which the upper part of its course is encumbered. The upper part of the Allen Valley has no doubt also been occupied by ice. The ice streams, except near their source, have probably not been deep, and their principal topographic effect has been to fill valleys, disturb drainage, and build dams behind which lakes have grown. Their direct action probably has not extended far beyond the foot of the mountain range in which they originated.[a]

[a] Mr. Schrader has found striated pebbles on the hills back of Bergman. If these have been deposited in their present position by ice, the valley glaciers have had a greater maximum extent than the writer has indicated.

ECONOMIC GEOLOGY.[a]

COAL.

Dall River.—In the bed of Coal Creek, about 1 mile above its confluence with the Dall River, there is an outcrop of lignite with irregular clay streaks, which measures, as far as can be determined from the imperfect exposures, approximately 11 feet in thickness. At the base of the exposure is 4 or 5 feet of firm, bright lignite, while the remainder is soft, dirty, and of poor quality. Blocks of the coal have been washed down the creek and some distance down Dall River without breaking up; but certain portions of the seam slake rapidly when exposed to the atmosphere. Although no opportunity was afforded for making practical tests, the lower 4 or 5 feet of this seam is believed to be a lignite of good quality, while the remainder is probably of no value. This coal is contained in soft gray, buff, or black shales, which are supposed to be Tertiary (Kenai series).

Kowak River.—The Tertiary sediments in which the lignites occur outcrop along the banks of the Kowak between the mouths of the Squirrel and Reed rivers, and it is probable that they occur in the lower valleys of the Reed, Salmon, Kaligurecheark, and Hunt rivers. The Kowak occurrences are mentioned by Stoney and are more fully described by Cantwell and McLenegan, who attempted to use some of the coal as fuel in a steam launch, but with unsatisfactory results.

The coals occur in low bluffs along the river, interbedded with conglomerates and fire clays. Those sufficiently well exposed for examination are of poor quality and burn slowly, yielding abundant ash and the disagreeable gases which are characteristic of impure lignites. So far as could be determined, none of the coals outcropping here are more than 2 or 3 feet in thickness, and the majority of the seams are much thinner. Half a dozen, with a thickness of 6 or 8 inches, were examined during the reconnaissance. Economically the beds are valueless.

Coal is also reported in the valleys of the Kewalik and Buckland rivers, but this occurrence has not been confirmed.

[a] Two geologic maps have been prepared. One is a general map of the entire region studied, upon which the facts gathered in the reconnaissance have been expressed by patterns, while those gleaned from other sources are printed in red. This map is intended to serve an economic as well as a geologic purpose, the known gold occurrences being confined to the area of the Metamorphic complex and the known coal occurrences to the area of the Kenai series. Coal, however, may occur in the Bergman series, although none is known at present in these rocks.

The larger scale map is introduced in order to show in somewhat greater detail than is possible on the general map the distribution, relations, and character of the rocks in the vicinity of the Kowak-Allen portage.

GOLD.

Dall River.—Some prospecting has been done along this stream and a few colors may be found on the bars and on the rim rock where exposed in the upper valley, but no occurrences of sufficient richness for development are known.

Allen River.—Colors are also found on the upper Allen and some of its tributaries, including Helpmejack and Rocky Bottom creeks. During the summer of 1901 two prospectors were at work on the latter stream, but practically no work has been done here since the 1898 rush, when a number of men from the Koyukuk prospected in different parts of the Allen Valley and found colors in a number of localities, but developed nothing rich enough to justify any considerable expenditure of time or money.

Noatak River.—On a tributary of the Noatak, which is reached by a short winter portage from the head of the upper Reed River, two or three claims were staked in 1898, from which a little coarse gold is reported to have been washed. It is said that no fine gold occurs with the coarse, and that other ground in the vicinity of these claims is barren. The claims are located 5 or 6 miles from the main Noatak River, on a small mountain stream with a narrow valley, and but a small quantity of gravel in sight.

Several men with outfits intended to remain in Kotzebue Sound during the winter of 1901–1902 and advance supplies up the Noatak, with the idea of doing further prospecting there.

Kowak River.—Fine colors may be washed from the gravel of the upper Kowak and many of its tributaries, and this fact, duly exaggerated and well advertised in a sufficiently mysterious fashion, led to the stampede of 1898. So far as known, not a single strike of consequence was made, and but little prospecting has been done since, although a few white men were in the valley last season. Such colors as are found usually come from the northern tributaries of the river, although a small amount of very fine gold is reported at the head of the Pick.

Kotzebue Sound.[a]—Late in the fall of 1900 a movement began from the Nome region toward the shore of Goodhope Bay and adjacent parts of Kotzebue Sound, and as soon as navigation opened in July, 1901, the supply station of Deering was established at the mouth of the Ipnechuk River. Many prospectors and miners came in from the more southerly areas at this time and the Fairhaven mining district was created, and so defined as to include Goodhope, Cripple, Sullivan, Ipnechuk, Kugruk or Swan, and Kewalik rivers, together with the northwestern portion of the Buckland drainage system.

[a] For much information concerning the Fairhaven district the writer is indebted to Mr. R. J. Wynkoop, deputy recorder.

In the western part of this district those creeks which have been the scene of the most active operations during the past season and are most favorably reported upon are Old Glory, Perry, and Hannum and its tributaries. The gold from Old Glory Creek, which may be regarded as a fair sample of the region, is dark, rather fine, and assays[a] between $16.50 and $17 per ounce.

Candle Creek, concerning which encouraging reports have been made during the fall and early winter, is a western tributary of the Kewalik River, which it joins about 6 miles above the head of Spafarief Bay. The stream is 20 or 25 miles long, and with its tributaries was all staked during the early summer. Some unsystematic work was done during the fall of 1901 by snipers, usually working with rockers. Their operations were confined to the creek bed, but it is uncertain whether bed rock was reached in more than one or two instances. The width of the pay was not determined, nor in many cases the depth of the gravel. The latter is given at one or two localities as about 2½ feet. The gold, of which $20,000 to $25,000 is estimated to have been taken out during the late summer, is dull in color, considerably flattened, and assays nearly $17.

Dome, Minnehaha, Windy, Virginia, and Alder creeks, just west of Candle, have been prospected, and are reported to give good indications.

Beach diggings of limited extent have been carried on near the mouth of Alder Creek, and are reported to yield $8 or $10 per day to the man. The gold here is fine, and is evidently derived immediately from the dark-gray schists which form the bluffs back of the beach. Bed rock is reached at a distance of about a foot under the shingle of the beach, and the gold is taken from its surface. Some threads of wire gold are seen among the washings.

One bench claim has been located at the mouth of Chicago Creek, a tributary of Swan River, and is reported to prospect well.

Late in the fall of 1901, when exaggerated reports began to reach Nome of the Candle Creek finds, several boat loads of supplies were shipped into the sound, and a number of people accompanied the supplies, with the idea of wintering there. Besides these, many went overland after the snow fell. The work of another season will be required to determine whether the richness of the Candle Creek district is sufficient to justify the stampede, which has assumed rather large proportions.

NATIVES.

YUKON VALLEY.

At the mouth of the Dall River is a settlement of the Yukon Indians, who fish and hunt in the immediate vicinity of this stream. One or two of the more experienced men in the tribe occasionally act as river pilots through the Yukon Flats, and for this work are well paid. Others, besides their fishing and hunting,

[a] Assays by Mr. E. T. Allen, U. S. Geol. Survey.

work in the near-by wood camps or for traders at the various stations, receiving their pay in clothing and food supplies. They are quite independent and generally decline to work for strangers for less than $5 per day, and unless they are in need of supplies they may refuse altogether.

On the Kanuti River is a similar fishing settlement of perhaps 75 Koyukuk natives. They are very generally supplied with food and clothing of white manufacture through the work which they do for the Koyukuk miners, or by the exchange of game and furs for articles kept by the traders at the various stations.

KOWAK VALLEY.

Much the most enterprising and reliable of the native peoples encountered are the Eskimos of the Kowak Valley. Several young men belonging to this tribe were at work on the Koyukuk in 1901 and proved themselves very efficient laborers, contrary to the usual rule among natives. One was engaged as a guide from Bergman to the head of the Kowak, and he remained with the party until Kotzebue Sound was reached. He proved himself an expert boatman and his knowledge of the country was intimate, and, so far as could be determined, reliable. He seemed to take particular pains to answer inquiries truthfully. Others of his tribesmen had gone to Nome and to the Yukon in search of employment and its return in the much-coveted white man's food and wearing apparel. All the members of this tribe seem intelligent and imitative, and are very anxious to learn the English language and civilized ways. They are highly regarded by all of the whites who have visited the region in which they live.

The highest settlement of the Kowaks is near the outlet of Lake Selby, about 10 miles above Pah River, and from this point down to Kotzebue Sound native houses are frequently seen and there are constant signs of their occupancy of the valley. The estimated total number living along the Kowak in 1901 was 250. Mr. Samms, the missionary on Kotzebue Sound, after a careful estimate made during the winter of 1898, placed the number living in the valley at that time at 500. They are undoubtedly decreasing in numbers, but probably not at so rapid a rate as the difference in these estimates would indicate. Many of the prospectors who left the country in the spring of 1899 gave their outfits to natives, and these, believing that white men would continue to come into the valley, did not make their usual preparations for winter, so that numbers perished from exposure and starvation during the year or two following. Others have followed the white men to adjacent fields, and so there has been a decrease in the population of the valley without a decrease in the numbers of the tribe. A part of the difference may also be accounted for through the fact that Mr. Samms's estimate was made in winter, when all the Kowaks were in their winter homes, while the writer's was made during the summer season, when many were away on trading trips.

CLIMATE.

GENERAL.

Winter temperatures of 60° or 70° below zero are reached for a few days at a time in this interior region adjacent to the Arctic circle, but during these severely cold periods it is usually perfectly calm. The more dangerous times are those of higher temperatures and wind. At such times man can not face the gales and live. Much of the early and late winter weather, however, is not more severe than that in the north-central portion of the United States, and persons who have wintered on the Kowak or the Koyukuk prefer this season for the transportation of supplies and for travel generally, the air being dry and many days in each month bright and clear.

The summers are short but warm enough to be pleasant, the period from the middle of June to the middle of September, and in favorable years to October, being available for travel by the waterways or for prospecting. June and July are usually bright and clear, but after August 1 rains are to be expected, which often continue until freezing weather in September. There are then a few weeks of bright, cool, clear weather intervening between the beginning of freezing and the beginning of snowfall, which in many respects are the pleasantest part of the year, the mosquitoes and gnats, such intolerable nuisances during the summer, having disappeared entirely.

OPEN SEASON.

Lieutenant Stoney reports that in the fall of 1885 the Kowak River became clogged with ice on October 1, and that by the 13th it was frozen from bank to bank, and remained closed for the winter. In the spring of 1886 the ice cracked and began drifting on the 19th of May, and by June 3 the river was clear. In the fall of 1898 the ice did not begin to form until October 13. Three days later men and dogs were traveling over it. By June 1, 1899, the ice was gone. In the fall of 1900 the Dall River was frozen over on October 13, and ice was running on the Yukon, but the latter stream did not close until November 5. The following spring the ice broke on the Yukon at the mouth of the Dall on May 24, and the latter river was clear on the 27th.

The ice breaks first near the sources of the streams, and gorges are formed as this loose ice packs against the main body in its passage downstream. In 1901 the ice broke on the upper Yukon at the foot of Lake Laberge on May 18. A steamer which left for Dawson on that date arrived at the latter city on the 23d, one day before the ice broke at Fort Hamlin and several days before the Yukon was navigable there. At Bergman, on the Koyukuk, the ice began to move on the 29th of May, and by the 6th of June the river was open for

navigation. The Noatak is reported to free itself early in June ordinarily, but Kotzebue Sound is icebound until a much later date, so that the Noatak can not be reached by water often for some weeks after it is clear. In favorable seasons the sound is free from ice early in July, but during unfavorable years it may remain closed until August, so that the Noatak natives, following the ice down that river, are sometimes compelled to camp at its mouth for a month before they can reach Kikitaruk, almost in sight across the entrance to Hotham Inlet.

METEOROLOGIC DATA.

In the following tables the immediately available meteorologic data for the Dall, Koyukuk, and Kowak river valleys are assembled.

Meteorologic observations on Kowak River and vicinity.

Month.	Temperature.			Fair days.	Days of rain or snow.	Authority.	Locality.	Comment.
	Minimum recorded.	Maximum recorded.	Mean.					
1885.								
July	32	70	49	.....	.....	Lieutenant Stoney	Kowak River	Lieutenant Stoney publishes only temperatures, but these are summarized from records carefully made, with spirit thermometer.
Aug	32	68	47	.....	.....	do	do	
Sept	5	69	39	.....	.....	do	do	
Oct	−4	46	16	.....	.....	do	do	
Nov	−44	15	−9.5	.....	.....	do	do	
Dec	−65	29	−12.4	.....	.....	do	do	
1886.								
Jan	−70	31	−12.4	.....	.....	do	do	
Feb	−65	26	−22.5	.....	.....	do	do	
Mar	−38	36	−3.8	.....	.....	do	do	
Apr	−22	49	13	.....	.....	do	do	
May	14	65	35	.....	.....	do	do	
June	32	74	49	.....	.....	do	do	
1898.								
June	.....	.....	.....	.....	16	McElwaine	do	
July	.....	.....	57.6	.....	11	do	do	
Aug	.....	.....	50.15	.....	18	do	do	
Sept	.....	.....	.....	.....	12	.....	.....	
1899.								
Feb	−67	10	34.27	.....	.....	.....	.....	
1900.								
Oct	−21	44	17	4	7	Heyman	Mouth Dall River	The temperatures given as mean are means of the morning and evening observations only.
Nov	−43	10	−16.5	20	5	do	do	
Dec	−55	6	−19	12	6	do	do	
1901.								
Jan	−66	18	−31	23	6	do	do	Observations taken three times per day.
Feb	−56	38	−22	18	4	.....	.....	
Mar	−45	23	−1	14	11	Heyman	Mouth Dall River	Observations made during thirty days only in May.
Apr	−4	49	21	17	4	do	do	
May	19	70	33	13	3	do	do	

Meteorological observations on Kowak River and vicinity—Continued.

Month.	Temperature.			Fair days.	Days of rain or snow.	Observer.	Locality.	Comment.
	Minimum recorded.	Maximum recorded.	Mean.					
1885.								
June...	49.5	79.5	63	9	3	Poto, U. S. G. S	Dall River.....	Observations began June 16. Lowest record of minimum thermometer 33.5, June 24.
July ...	44	80.75	58	19	4	.....do	Koyukuk drainage...	Minimum thermometer recorded 16, July 31.
Aug ...	35.5	68	48	11	15	.....do	Kowak River.....	Minimum recorded 20, August 1.
Sept ...	41	55.5	45	5	7	.....do	Kotzebue Sound.....	Observations continued through first nineteen days only.

FISH AND GAME.

Before the advent of white men salmon were the main food of the natives of the Koyukuk and the Kowak. The fish, although perhaps decreasing in numbers, still run plentifully throughout the late summer and fall, and are dried for winter use, although through the advent of traders and stores they are of somewhat less importance to the natives as a food supply.

The Koyukuk Indians were found at their fishing stations about the middle of July, where they were awaiting the arrival of the salmon. Early in August this fish had ascended the Kowak to beyond the one hundred and fifty-fifth meridian and were abundant in the spawning grounds in the shallows of the river or its tributaries all along the stream from this point to the sea, and the natives, from Lake Selby down, were busy with their summer's catch.

A white fish of excellent flavor is netted along all of these rivers in summer, and numbers of pike are caught, especially in the delta of the Kowak and in the sloughs of this and other streams where their is but little current and water plants flourish. Greyling may be found in all of the clear-water streams and a large trout is present in the mountain lakes. A small salmon of most excellent flavor is caught in large numbers by the whites in Kotzebue Sound in September, and cured for their winter use.

Waterfowl are plentiful along all of the streams, since they breed in great numbers in the lakes and ponds of the tundra, and while they are not evenly enough distributed to be depended on for food, may often be shot in sufficient numbers to add a very agreeable variety to the bill of fare. We killed numbers of geese and ducks on the Kanuti River and on the lower Kowak. The geese, while plentiful, are wary and difficult to capture unless hunting is made a business. Both the Canada goose and the American white-fronted goose were observed.

Young ducks, just before migrating in the fall, are fat and easily shot. They are particularly abundant along the marshes of the coast. Widgeon, green-wing teal, pintail, butterballs, and harlequins are among the varieties recognized. Swans, sandhill cranes, snipe, and plover are seen, but less frequently. Probably the most valuable food bird, because of its very general distribution, is the willow ptarmigan. It is very abundant on the tundra, where it seeks shelter in the willow and alder patches, but is less abundant in the mountainous districts. Another somewhat smaller ptarmigan inhabits the rocky sides and tops of the mountain. It is less numerous and found in smaller coveys than the bird of the lowlands. A few Canada grouse live in the spruce forests.

There are caribou in the region about the head of the Kanuti River, and herds are occasionally reported on the hills between the upper Kowak and the Koyukuk, but the Kowak natives now are generally forced to cross over to the Noatak Basin, or eastward to the head of the Totsenbet River, in order to secure caribou skins for clothing. A few white mountain sheep are killed in the high country about the head of the Allen, the Colville, and the Kowak, but this game is not at all abundant. Black bear are distributed, although not anywhere numerous, throughout the district, and some of the brown variety are shot along the lower Kowak and Noatak. Moose are not plentiful anywhere. They are more abundant toward the south and east in the Yukon drainage basin, where there is a heavier timber growth. Natives said that a few are known as far north as Chandlar Lake, in the Colville drainage basin. This is beyond the spruce limit, but cottonwood groves may give them the necessary shelter. At present they seem to be entirely absent about the upper Kowak, although it is but a few years since they occupied this region.

Smaller animals are plentiful in certain localities. The flesh of the muskrat, which is very abundant in the Kowak delta, is used as food by the Eskimos there, and its pelt is made into clothing when caribou or reindeer skins can not be obtained. Red and white foxes are caught in limited numbers, and occasionally marten, beaver, and mink skins are offered for sale.

VEGETATION.

Spruces, "cottonwoods," or poplars, and birches are to be found at the lower levels throughout the entire district traversed from Fort Yukon to Deering, with the single exception of the area along the southern and eastern shores of Kotzebue Sound. Spruce trees extend down half way through the Kowak delta and approach very close to the shores of Hotham Inlet, near the mouth of Noatak. On this river for a distance of 75 or 80 miles they are reported to grow in sufficient size and numbers for the construction of cabins.

NEAR HEADWATERS OF HELPMEJACK CREEK, ABOUT 3 MILES BELOW BEGINNING OF KOWAK PORTAGE.

Shows willow growth along streams and illustrates character of navigation along the approaches to the portage.

Within the Kowak Valley the mountain slopes, up to an elevation of 2,000 feet near the source of the stream, and to somewhat lower elevations near its mouth, are generally clothed with spruce, both the white and black varieties growing here. Along the flats of the middle valley trees occur only along the streams, or in clumps here and there, in spots where the drainage is better. Sixteen or 18 inches is about the maximum diameter attained, and the majority of the trees are smaller.

Birches grow in favorable localities on the lower hillsides, and poplars, including both balm of Gilead and the aspen, the latter less common than the former, on gravel knolls and ridges.

Many varieties of willows, varying in size from small trees to tiny shrubs but 2 or 3 inches high, line the banks of the waterways, where the larger varieties frequently form dense thickets. Alders occur at the lower levels and on the mountain slopes well above timber line.

In the valleys of the Allen, Kanuti, and Dall rivers arboreal vegetation is similar to that along the Kowak, except that the timber line rises somewhat toward the south and east to about 2,500 feet on the Dall, and the trees increase slightly in size and numbers, while the treeless tundra areas are not so extensive.

Grasses grow in patches as far north as our work extended, and in sufficient amount to furnish subsistence for pack animals during the summer months. Rye grass, blue grass or red-top, and a variety of bunch grass may be mentioned as among the more usual species, and with them may be associated the coarse cotton grass belonging to the sedge family.

Among the wild fruits of the region the red currant is sparingly distributed. The cloud berry, more usually called the salmon berry, grows on the tundra everywhere. The bilberry, one of the huckleberry family, is of very wide distribution, and the mountain and high-bush cranberries, as well as the bunch berry, are occasionally found. Docks and sorrels, whose leaves may be eaten, grow sparingly; and a species of *hedysarum*, with edible roots, known to the natives as "muchet," and used by them as a food, grows on sand and gravel bars along the streams.

The characteristic growth of the tundra is sphagnous, and the higher slopes and rocky tops of the mountains are covered with mosses and lichens of many shades, from the white or cream of the reindeer moss to the dark greens, reds, and blacks of the other lichens and mosses. Hardy and often showy flowers are abundant during the short summer season and brighten up the rather somber landscape wonderfully.

Collections were made during the season by Mr. W. L. Poto when the exigencies of the other work permitted, and these have been submitted to Mr. Coville for identification.

LIST OF PLANTS COLLECTED IN NORTHERN ALASKA BY W. L. POTO IN 1901.

Identified chiefly by FREDERICK V. COVILLE and W. F. WIGHT.

POLYPODIACEÆ (Fern family).

DRYOPTERIS FRAGRANS (L.) Schott.

Fern quite common. Collected on Allen, Kanuti, and Kowak rivers.

FILIX FRAGILIS (L.) Underwood.

Fern observed on bluffs near Kowak River, below mouth of Squirrel River. August 30.

WOODSIA GLABELLA R. Br.

Fern observed on bluffs near Kowak River, below mouth of Squirrel River. August 30.

WOODSIA ILVENSIS (L.) R. Br.

Fern observed on rocky cliff, 35 miles above the mouth of Allen River, near camp of July 23.

PINACEÆ (Pine family).

PICEA CANADENSIS (Mill.) B. S. P. White spruce.

Variety of spruce found on lower half of Kowak River. Grows to 40 or 50 feet high and 15 inches in diameter. Above mouth of Squirrel River. August 30.

Collected also about 30 miles below Walker Lake, near timber line.

PICEA MARIANA (Mill.) B. S. P. Black spruce.

Near camp about 20 miles below Walker Lake. Usual variety of spruce found in river bottoms. Grows to 40 or 50 feet high and 15 inches in diameter. August 14.

Collected also on Dall River.

JUNIPERUS.

Small creeping plant, 6 to 20 inches high. Observed occasionally in mossy places. Walker Lake. August 12.

POACEÆ (Grass family).

ARCTAGROSTIS ARUNDINACEA ALASKANA Vasey.

Grass abundant along Helpmejack Creek, near camp above Beaver City. July 26.

CALAMAGROSTIS CANADENSIS ACUMINATA Vasey?

Grass quite common in low places along portage between Kowak River and Helpmejack Creek, above Beaver City. August 3.

POA NEMORALIS L. Blue grass.

Collected about 10 miles below Caribou Mountain, July 8, and on the Allen.

COLPODIUM FULVUM Trin.

Observed in marshy place. Not very common. About 20 miles below Walker Lake, near camp of August 14.

FESTUCA ALTAICA Trin. Bunch grass.

Dall River trail, near Dall City. June 29.

ELYMUS INNOVATUS Beal. Rye grass.

Grass rather common on sandy bottoms, about 15 miles above mouth of Allen River, near camp of July 20.

CYPERACEÆ (Sedge family).

ERIOPHORUM CALLITHRIX Cham.? Cotton grass.

Plant very common everywhere. Grows occasionally in large patches. Collected about 50 miles above Hotham Inlet, at camp of August 29.

CAREX MACROCHÆTA Mey.

Kanuti River, near camp at Caribou Mountain. July 6.

CAREX UTRICULATA Boott.

Common along Helpmejack Creek, near camp above Beaver City. July 26.

CAREX VULGARIS Fries.

Dall River trail, 4 miles above Dall City. June 29.

MELANTHACEÆ (Bunch-flower family).

ZYGADENUS ELEGANS Pursh.

Plant quite common. Observed in moist places along river banks. About 3 miles below Walker Lake, near camp of August 10.

LILIACEÆ (Lily family).

ALLIUM SIBIRICUM L. Onion.

Plant quite common on beach. Abundant on Koyukuk. Walker Lake. August 12.

IRIDACEÆ (Iris family).

IRIS SETOSA Pall.

Plant not common. Seen occasionally along banks in rather sandy places. Near camp of August 17, about 45 miles below Walker Lake.

ORCHIDACEÆ (Orchid family).

HABENARIA OBTUSATA (Pursh) Richards.

Plant not common. Observed in sandy spot on Helpmejack Creek, near camp above Beaver City. July 26.

SALICACEÆ (Willow family).

POPULUS BALSAMIFERA L. Balm of Gilead.

Very common along rivers. Grows to about 40 feet high. Collected on Allen and upper Kowak rivers.

POPULUS TREMULOIDES Michx. Aspen.

Tree seems to grow chiefly on low hills; up to 20 feet high. Bark light colored. Near camp, about 10 miles below Walker Lake. August 13.

SALIX ALAXENSIS (Anders.) Coville. Alaska willow.

Tall, slender willow, very common along river, from 12 to 25 feet high. Collected about 45 miles below Walker Lake, August 17, and on Dall River.

SALIX ARBUSCULOIDES Anders.

Willow, common, grows 10 to 20 feet tall; slender. August 28. Collected on Dall, Allen, and Kowak rivers.

SALIX BEBBIANA Sargent.

Dall River, 65 miles above mouth.

SALIX FUSCESCENS Anders.

Willow small and creeping, from 3 to 10 inches high. Common in high places. Collected on Kowak portage, between the Allen and Walker Lake. July 3.

SALIX GLAUCA L.

Bushy willow, 3 to 10 feet high. Common along streams from the Yukon to the lower Kowak.

SALIX PULCHRA Cham.

Willow quite common on the Allen and upper Kowak, generally about 6 feet high. Grows in clumps.

SALIX RETICULATA L.

Small plant, common on divide in mossy places. Headwaters of Kowak River. August 8.

SALIX.

Dall River, 75 miles above mouth, June 25; Allen River, 30 miles above mouth, 2 to 4 feet high, July 21; along Helpmejack Creek, about 5 feet high, near camp of July 26; on bank of small stream near camp of August 20, about 4 feet high.

MYRICACEÆ (Bayberry family).

MYRICA GALE L. Sweet gale.

Dall River, 75 miles above mouth. June 25.

BETULACEÆ (Birch family).

BETULA ALASKANA Sargent. Birch.

Very common tree on mountain slopes; grows up to 50 feet high, trunk 7 or 8 inches in diameter. Bark white and papery.

BETULA GLANDULOSA ROTUNDIFOLIA (Spach) Regel.

Dall River trail, 10 miles above Dall City. July 1.

ALNUS ALNOBETULA (Ehrh.) Koch. Alder.

Dall River, 35 miles above mouth. June 21.

POLYGONACEÆ (Smartweed family).

RUMEX. Dock.

Plant not common. Observed in rather moist places. Grows from 15 to 30 inches high. Kanuti and Upper Kowak.

OXYRIA DIGYNA (L.) Camptd. Mountain sorrel.

Plant not common. Observed on gravel bank of Helpmejack Creek near camp above Beaver City. July 26.

POLYGONUM ALPINUM ALASKANUM Small.

Conspicuous plant 1½ to 4 feet high, on moist hillsides near Allen River.

POLYGONUM PLUMOSUM Small.

Headwaters of Kanuti River, a branch of the Koyukuk. July 3.

POLYGONUM VIVIPARUM L.

Plant observed frequently in moist places on Kowak River; near camp at Walker Lake. August 10.

PORTULACACEÆ (Portulaca family).

CLAYTONIA SARMENTOSA C. A. Meyer.

Observed in low mossy place near Helpmejack Creek, near camp above Beaver City. July 26.

ALSINACEÆ (Chickweed family).

ALSINE LONGIPES (Goldie) Coville.

Dall River trail, 3 miles above Dall City. June 29.

MERCKIA PHYSODES Fisch.

Kanuti River, a branch of the Koyukuk. Collected about 10 miles below Caribou Mountain. July 8.

ARENARIA.

Kanuti River. Collected about 20 miles below Caribou Mountain. July 9.

ARENARIA ARCTICA Stev.

Dall River trail, 12 miles above Dall City. July 1.

MOEHRINGIA LATERIFLORA (L.) Fenzl.

Dall River, 35 miles above mouth. June 21.

RANUNCULACEÆ (Buttercup family.)

ACONITUM DELPHINIFOLIUM DC. Monkshood.

Flowers observed occasionally along Helpmejack Creek and Allen River.

ANEMONE RICHARDSONI Hook.

Dall River, 75 miles above mouth. June 26.

PAPAVERACEÆ (Poppy family).

PAPAVER RADICATUM Rottb.

Kanuti River. Collected about 20 miles below Caribou Mountain. July 9.

CAPNOIDES PAUCIFLORUM (Willd.) Kuntze.

Kanuti River, 4 miles above Caribou Mountain. July 6.

CAPNOIDES SEMPERVIRENS (L.) Kuntze.

Dall River trail, 3 miles above Dall City. June 29.

BRASSICACEÆ (Mustard family).

SISYMBRIUM.

Plant observed on hill, 2½ to 4 feet high. Along beach on Hotham Inlet, 6 miles from Quaker Mission. Not common. September 5.

CARDAMINE.

Plant not common. Found in sandy places along Lower Kowak River.

ALYSSUM AMERICANUM Greene.

Kanuti River. Collected about 10 miles below Caribou Mountain. July 8.

PARRYA.

Kanuti River, 4 miles above Caribou Mountain. July 6.

SAXIFRAGACEÆ (Saxifrage family).

SAXIFRAGA.

Plant seen frequently on hillsides near Allen River. From 6 to 18 inches high.

SAXIFRAGA TRICUSPIDATA Retz.

Kanuti River. Collected about 10 miles below Caribou Mountain. July 8.

PARNASSIA KOTZEBUEI Cham. and Schlecht.

Inconspicuous plant along Allen River in moist shady spots. July 23.

RIBACEÆ (Currant family).

RIBES HUDSONIANUM Richards.

Dall River, about 20 miles above the mouth. June 23.

RIBES RUBRUM L. Red currant.

Dall River, 35 miles above mouth. June 21.

ROSACEÆ (Rose family.)

SPIRÆA BETULIFOLIA Pall.

Dall River, near Dall City. June 27.

RUBUS ARCTICUS L.

Kanuti River. Collected about 20 miles below Caribou Mountain. July 9.

RUBUS CHAMÆMORUS L. "Salmon berry," Cloud berry.

Dall River, 55 miles above mouth. June 27.

POTENTILLA FRUTICOSA L.

Dall River, 75 miles above mouth. June 26.

COMARUM PALUSTRE L.

Plant observed in low, marshy ground. Not common. About 20 miles below Walker Lake. August 14.

DRYAS INTEGRIFOLIA Vahl.

Dall River trail, 2 miles above Dall City. June 29.

SANGUISORBA MEDIA L.

Plant rather common. Observed near upper Kowak River in sandy places; 15 to 30 inches high. August 13.

ROSA ACICULARIS Lindl.

Kanuti River. Collected about 10 miles below Caribou Mountain. July 8.

VICIACEÆ (Vetch family).

LUPINUS.

Dall River, 75 miles above mouth. June 26.

ASTRAGALUS ALPINUS L.

Dall River, 75 miles above mouth. June 26.

HEDYSARUM AMERICANUM (Michx.) Britton.

Thirty miles above mouth of Allen River. Very common. Observed frequently on Kanuti and Allen rivers, 12 to 24 inches high, in clusters. Root used for food by Indians, raw and cooked. Best after frost. Indian name "muchet." July 21.

VIOLACEÆ (Violet family).

VIOLA LANGSDORFII Fisch.
Kanuti River, near headwaters. July 5.

ONAGRACEÆ (Evening primrose family).

CHAMÆNERION LATIFOLIUM (L.) Sweet. Fire weed.
Kanuti River. Collected about 10 miles below Caribou Mountain. July 8.

CORNACEÆ (Dogwood family).

CORNUS CANADENSIS L.
Plant found on portage between the Allen and the Kowak. August 3.

PYROLACEÆ (Wintergreen family).

PYROLA ROTUNDIFOLIA L.
Dall River, 35 miles above mouth. June 21.

MONESES UNIFLORA (L.) Gray.
Plant not common. Observed in low mossy spot on Helpmejack Creek, above Beaver City. July 26.

ERICACEÆ (Heather family).

LEDUM DECUMBENS (Ait.) Lodd.
Dall River, 75 miles above mouth. June 26.

CHAMÆCISTUS PROCUMBENS (L.) Kuntze.
Dall River trail, 11 miles above Dall City. July 1.

CASSIOPE TETRAGONA (L.) D. Don.
Dall River trail, 8 miles above Dall City. June 30.

ANDROMEDA POLIFOLIA L. Wild rosemary.
Dall River trail, 4 miles from Dall City. June 29.

CHAMÆDAPHNE CALYCULATA (L.) Moench. Leather-leaf.
Dall River, 75 miles above mouth. June 26.

VACCINIACEÆ (Huckleberry family).

VACCINIUM ULIGINOSUM L. Bilberry.
Very generally distributed.

VACCINIUM VITIS-IDÆA L. Mountain cranberry.
Dall River, 75 miles above mouth. June 26.

PRIMULACEÆ (Primrose family).

DODECATHEON FRIGIDUM Cham. and Schlecht. Shooting star.
Kanuti River, in the vicinity of Caribou Mountain. July 6.

GENTIANACEÆ (Gentian family).

GENTIANA.

Plant rare. Very few observed on sandy beach, Walker Lake. August 12.

POLEMONIACEÆ (Polemonium family).

PHLOX SIBIRICA L.

Dall River trail, 2 miles above Dall City. June 29.

POLEMONIUM.

Kanuti River, near the headwaters. July 5.

BORAGINACEÆ (Borage family).

ERITRICHUM SPLENDENS Kearney.

Kanuti River. Collected about 15 miles below Caribou Mountain. July 6.

MERTENSIA PANICULATA (Ait.) Don.

Conspicuous blue flower in birch woods. Abundant. Dall River, 35 miles above mouth. June 21.

SCROPHULARIACEÆ (Figwort family).

CASTILLEJA PALLIDA Kunth.

Plant not common. Observed on bank in rather mossy place, 65 miles above mouth of Allen River. July 23.

PEDICULARIS.

Plant not very common. Observed in mossy spot along Helpmejack Creek, above Beaver City. July 26.

PEDICULARIS.

Headwaters of Kanuti River. July 3.

PEDICULARIS LANATA Willd.

Dall River trail, 8 miles above Dall City. June 30.

RUBIACEÆ (Madder family).

GALIUM BOREALE L.

Flower quite common; found generally on rocky cliffs, Allen River. Collected on Kanuti River.

VIBURNACEÆ (Honeysuckle family).

VIBURNUM PAUCIFLORUM Pylaie. High-bush cranberry.

Dall River, 75 miles above mouth. June 25.

LINNÆA BOREALIS L. Twin flower.

Flower quite common in mossy places. Collected near Beaver City. July 26.

VALERIANACEÆ (Valerian family).

VALERIANA CAPITATA Pall.

Flower quite common in moist places along Allen River and Helpmejack Creek. Collected above Beaver City. July 26.

CAMPANULACEÆ (Bluebell family).

CAMPANULA LASIOCARPA Cham.

Plant observed on hill at 2,000 feet. Upper Kowak River. Not very common. August 14.

CICHORIACEÆ (Chicory family).

TARAXACUM. Dandelion.

Only two plants observed. About 15 miles above the mouth of Allen River. July 20.

CARDUACEÆ (Thistle family).

SOLIDAGO. Goldenrod.

Flower not very common. Collected on Walker Lake and Allen River.

ANTENNARIA.

Dall River trail, 10 miles above Dall City. July 11.

MATRICARIA INODORA L.

Plant observed growing in clusters along beach at Nimiuk Point, on Hotham Inlet. September 3.

TANACETUM.

Plant observed along bank of the lower Kowak River in gravel.

ARTEMISIA TILESII Ledeb.

Plant abundant along the Lower Kowak and Hotham Inlet. Grows 2 to 3½ feet high. September 5. Upper Kowak River, 1½ to 2½ feet high. August 10.

PETASITES.

Kanuti River, near its source. July 5

ARNICA.

Dall and Kanuti rivers.

SENECIO LUGENS Richards.

Plant rather abundant. Grows from 1 to 2 feet high in sandy places, a few miles from Walker Lake. August 12.

SENECIO PSEUDO-ARNICA Less.

Plant observed on gravel beach along Kotzebue Sound near Cape Blossom. September 7.

SAUSSUREA.

Plant rather abundant along Upper Kowak.

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O

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[Professional Paper No. 10.]

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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE

CLAYS OF THE UNITED STATES

EAST OF THE MISSISSIPPI RIVER

BY

HEINRICH RIES

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

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THE CLAYS OF THE UNITED STATES EAST OF THE MISSISSIPPI RIVER.

By HEINRICH RIES.

NATURE OF CLAY.

The term clay is applied to a natural substance or rock which, when finely ground and mixed with water, forms a pasty, moldable mass that preserves its shape when air dried, and when burned changes to a hard, rock-like substance by the coalescence of its particles, through softening under the action of heat.

A microscopic examination of clay shows that it is made up of a great number of small mineral fragments of many different kinds and of varying shape, ranging in size from those which are under $\frac{1}{100}$ mm. in diameter (known as clay) up to grains of sand which are sufficiently large to be easily visible to the naked eye. The smaller particles predominate.

Since clays vary mineralogically they vary also chemically, but the plasticity may remain the same through a wide range of chemical composition, and this property is evidently not dependent on the chemical composition alone, but is due rather to some physical cause. The plasticity may be destroyed by heating the clay to a sufficiently high temperature to drive off the chemically combined water.

Although varying in their mineral composition, most clays are supposed to contain more or less of the mineral kaolinite (a hydrated silicate of alumina), which is commonly referred to as the clay base or clay substance. The adoption of the latter term has probably arisen from the fact that many have considered this mineral to be the cause of plasticity, an idea now known to be somewhat incorrect, because some of the most plastic clays contain but small quantities of kaolinite, and vice versa.

ORIGIN OF CLAY.

Clay is usually formed directly or indirectly from the decomposition of rocks containing feldspar, this change being due either to weathering or to exposure to certain acid vapors. This mineral changes to kaolinite, but the latter may also be

formed from quartz,[a] and even amphiboles and pyroxenes may yield hydrous aluminum silicates.[b]

A mass of kaolinite is known as kaolin, the former being the mineralogical name, the latter the rock term though the two are unfortunately often mixed.

Feldspar alone yields by its decomposition a mass of pure white clay, and the presence of quartz or white mica will interfere but little with its color. The admixture, however, of any minerals containing iron at once affects the tint of the kaolin and strongly discolors it, iron in fact being the most common coloring material which clays contain.

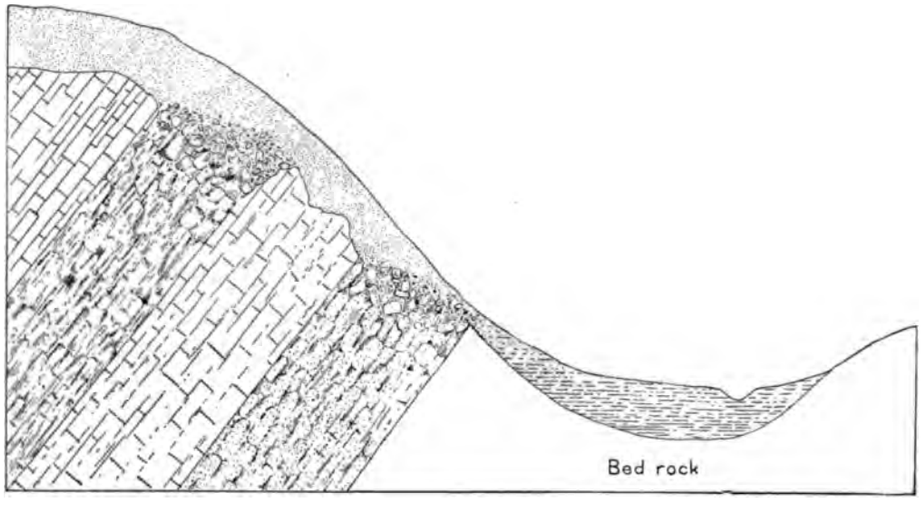

FIG. 1.—Section illustrating the formation of residual clay.

RESIDUAL CLAYS.

When a mass of feldspathic rock weathers down to clay and the latter remains at or close to the place of its origin the deposit is termed a residual one (fig. 1), since the clay thus formed represents the residuum of the rock decay, the soluble portions of the parent rock having been wholly or partly carried off. Residual clays are usually very impure and highly colored by iron, and since they are formed by weathering they show a gradual passage from the fully formed clay at the surface to the parent rock below, limestone residuals forming the only exception, the change from clay to rock in such cases being sudden. Residual clays often contain more or less angular fragments of undecomposed or partly decayed mineral matter, and these may

[a] Trans. Am. Inst. Min. Eng., Vol. XXX, p. 614. [b] Merrill, G. P., Rocks, Rock Weathering, and Soils, p. 21.

increase in number and size as the parent rock is approached. The depth of residual deposits varies with the depth to which the weathering has penetrated the parent rock and also with the surface slope on which the clay has been formed. On steep slopes residual clays seldom show great thickness, since they are easily washed away, but in valleys and on flat surfaces their thickness may be great. In the Southern States, in fact in the entire area south of the terminal moraine of the Glacial epoch (see p. 50), residual clays are abundant wherever the rock is weathered and the slope has been sufficiently gentle to permit them to remain. Along the line of the Appalachians the Cambrian and Silurian limestones are especially important sources of residual clays, because their decay has yielded a great mantle of this material. They are common in the Great Valley, notably at its southern end. The pre-Cambrian crystalline rocks have likewise formed an extensive residual deposit of similar character. These deposits will be referred to in more detail under headings relating to the different States and formations.[a]

VALUE OF RESIDUAL CLAYS.

Since residual clays are usually impure they are seldom of value for anything better than common brick or drain tile, although the finer parts are sometimes used for pottery. In rare instances they show great freedom from iron, notably in the case of the residual clays derived from the decomposition of pegmatite veins (western North Carolina) or highly feldspathic gneisses (Cecil County, Md). Those formed by the decay of some of the Cambro-Silurian schists in southeastern Pennsylvania and portions of the Knox dolomite may also be nearly white in color.

Analyses of residual clays.

	1.	2.	3.	4.	5.	6.	7.	8.
Alumina	22.17	20.47	19.64	14.74	31.76	26.43	21.764	18.98
Silica	55.42	58.63	61.66	76.78	52.03	54.54	72.164	70.83
Water	9.86	7.26	.....	4.894	15.55	9.87	4.758	5.45
Ferric oxide	8.3	8.58	7.54	1.64	Tr.	9.04	.99	1.24
Lime	.15	Tr.	Tr.	Tr.	Tr.	.....	.224	.24
Magnesia	1.45	1.42	Tr.	.389	.54	.....	.698	.02
Alkalies	2.49	4.00	2.32	1.557	.....	.....	5.139	2.59
CO_2	.....	.....	.....	.....	.....	.....	.....	1.02

1. From Knoxville limestone, Morrisville, Calhoun County, Ala.
2. Cartersville, Bartow County, Ga. (Georgia Geol. Surv., 1893).

[a] See also Russell, I. C., Subaerial decay of rocks and origin of the red color of certain formations: Bull. U. S. Geol. Survey No. 52.

3. Rockmart, Polk County, Ga. (Georgia Geol. Surv., 1893).
4. From chert, Graves County, Ky. (Kentucky Geol. Survey, Chem. Anal., Pt. III).
5. Blandford, Hampden County, Mass. (Tech. Quart., 1890).
6. Cary, Wake County, N. C.
7. From slate, Fogelsville, Lehigh County, Pa. (Pennsylvania Geol. Survey, Rept. D, p. 13).
8. Grand Rapids, Wood County, Wis. (Wisconsin Acad. Sci., 1870–1876).

SEDIMENTARY CLAYS.

Those plastic products of rock decay which do not remain over the parent rock are washed down into the brooks and rivers and carried on to the lakes or seas, where they are spread out over the bottom as bedded or stratified deposits of clay, to which the term sedimentary clay is given (fig. 2). The section of such a deposit

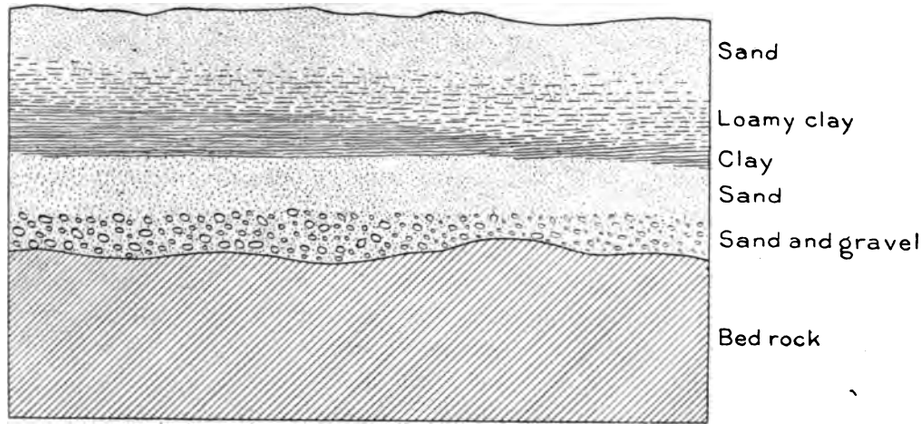

FIG. 2.—Section illustrating occurrence of sedimentary clay.

shows a series of layers which bear no genetic relation to the underlying rock. They may represent a section of many beds of very similar character or of widely different nature, some being sandy, others quite fine. By the accumulation of many beds of sediment on top of the clay the latter may become consolidated to form a bed of shale. The shale when ground and mixed with water, however, often yields a mass as plastic as common surface clay. In many regions where the rocks have been folded and metamorphosed the shale has been changed to slate. This alteration, being the result of pressure, and perhaps heat, has been sufficient to destroy the inherent property of plasticity, for the slates when ground and mixed with water will not develop a plastic mass. The shales that occur in association with the coal beds are often erroneously termed slate by miners, probably for the reason that many of them are hard and brittle and thus somewhat resemble true slate.

GEOLOGIC DISTRIBUTION OF CLAY, SHALE, AND SLATE.

Clays.—Sedimentary clays are commonly found in the younger geologic formations—that is, those ranging from the Cretaceous up to and including the Pleistocene. The Tertiary and Cretaceous clay beds of the eastern United States usually represent marine deposits, and may be of considerable extent, except where they were deposited in areas that were subject to shifting ocean currents, in which case they may be small and very irregular. This is true of many of our Coastal Plain clay deposits, for here beds of clay may pass horizontally into sand within a very short distance. The Pleistocene deposits also yield vast quantities of sedimentary clay which may have been formed under several different conditions, giving the following types:

(1) Lake clays; beds of clay laid down in the areas bordering the present Great Lakes during the time when the waters spread over a greater territory than they do now. This type may show great extent and thickness, but the clays are often calcareous. They are common in Wisconsin, Michigan, northern Indiana, and western New York.

(2) Estuarine clays, deposited in depressed valleys or estuaries of the sea or in lakes, and represented by certain Wisconsin types and those of the Hudson Valley, and by many Columbia clays along the Atlantic coast. These may also be of great thickness. They are usually impure and of widely different character at different localities.

(3) Pond clays, formed in small lakes or ponds scattered all over the Northern States north of the line of the terminal moraine. They are usually basin shaped and may or may not be extensive. They are found in many flat-bottomed valleys and are extensively worked for the manufacture of brick and tile.

(4) Moraine deposits, of irregular size and often lens shaped, occurring in moraines or glacial till. They are apt to be stony and very sandy, and are often calcareous. Very few of them are sufficiently extensive to support a large factory for a long period.

(5) River-terrace deposits, commonly sandy beds, representing mud and clay deposited by streams during periods of overflow. They underlie the flat terraces bordering many of our larger rivers and sometimes the smaller ones. In some valleys several terraces are found at different levels, and of these the lowest one is frequently overflowed during periods of high flood and the clay deposit thus added to. Clays of this type are worked along the Ohio and Mississippi rivers, the Tennessee, the Potomac, the Mohawk, and other streams. These deposits are used mostly for the manufacture of common brick and tile—in rare instances for paving brick and terra cotta. They are sometimes sufficiently fine grained to be employed in the manufacture of pottery.

Shales.—In the United States east of the Mississippi consolidated clays or shales are confined to the Paleozoic and Juratrias formations. They occur in unlimited quantities in rocks of Cambrian, Silurian, Devonian, Carboniferous, and Juratrias age. Considering them as a whole, those of the Carboniferous are the most important, and are extensively used in the manufacture of common brick, paving brick, pressed brick, terra cotta, firebrick, stoneware, etc. The Devonian shales are of less value, but where sufficiently free from grit to be plastic on grinding they are found to be a valuable source of clay. The Triassic shales have little commercial value.

Slate.—Slate is rarely used in the manufacture of clay products, although in a few regions it is ground up and mixed with some plastic clay for molding into brick. Such a mixture is usually made on account of some color-burning or refractory quality which the slate may possess.

PROPERTIES OF CLAY.

PHYSICAL PROPERTIES.[a]

Since these affect the commercial value of the clay to a very large extent, it may be well to mention them briefly. Under the physical properties of clay are included air and fire shrinkage, tensile strength, plasticity, fusibility, color, and slaking.

Air shrinkage.—This refers to the decrease in size which takes place during the air drying of the clay, and is due to the evaporation of the water which has been used to mix up the material. The amount of air shrinkage usually stands in direct relation to the quantity of water absorbed by the clay during the mixing or tempering. Since plastic clays absorb more water than lean or slightly plastic ones, they show a higher air shrinkage. The air shrinkage ranges from 1 to 2 per cent in very lean or sandy clays up to 8 or 10 per cent or possibly even more in very plastic material. The air shrinkage is a matter of considerable importance to the clay worker, for the reason that the greater the decrease in size of the clay product during drying the greater the danger of its warping or cracking. Clays with a high air shrinkage usually have to be dried very slowly and carefully, and the aim of the manufacturer, therefore, is to find a clay or make a mixture of clays which will not only have a low air shrinkage but will also stand rapid drying. The air shrinkage begins as soon as the clay has been molded or is taken from the machine, and all of the moisture is not driven off until the brick is placed in the kiln. The last portions of it evaporate in the early stages of burning, during which period great quantities of steam can be seen issuing from the chimneys of the kiln; this is known as the water-smoking process. Some clays part readily with the water contained in their pores, especially if they are sandy.

[a] For a more detailed discussion of these properties than can be given here, see The clays of New York and their uses: Bull. New York State Museum No. 3, p. 538.

Fire shrinkage.—All clays undergo a second diminution in volume during the firing, and this may range from 2 or 3 per cent up to 15 or 20 per cent or even more, showing just as much variation as the air shrinkage, but being due to different causes. The fire shrinkage does not really begin until the chemically combined water and carbonic-acid gas are driven out of the clay, consequently it commences at about dull redness. Although most clays shrink in burning, there are a few, such as those containing much quartz, which tend to expand at high temperatures.

Both the air shrinkage and the fire shrinkage may often be decreased by the addition of sand to the clay mixture.

Tensile strength.—The tensile strength of the clay is the resistance which it offers to rupture in its air-dried condition, and in most clays seems to stand more or less in relation to its plasticity—that is, very plastic clays often, but not always, have a high tensile strength. A high tensile strength in clay is desirable, since it helps the ware to resist cracking in drying and also permits it to stand handling better in its air-dried condition, but clays show a wide variation in respect to this property. The kaolins show the lowest tensile strength of all the clays, while the impure Gumbo clays of the Central and Western States show perhaps the highest cohesive power of any known. The following figures represent the usual range of tensile strength shown by different varieties of clay:

Tensile strength of different kinds of clay.

	Pounds per square inch.
Kaolins	5– 10
Brick clays	60–100 [a]
Pottery clays	150–200
Some very plastic clays	200–400

The work which has been done on the clays from different parts of the eastern United States indicates that the materials from any one formation may show a wide variation as regards cohesiveness. Thus among the Coastal Plain clays we find that those from New Jersey and Maryland, and even those from North Carolina, in many cases show but moderate tensile strength, while many of those obtained from the same formation in Alabama often show a very high tensile strength, as can be seen by an inspection of the tables of tests given on subsequent pages. Some of the residual clays of the Appalachian region show high strength; others show low strength, due to the presence of considerable sandy matter. The shales of the Paleozoic formations do not as a rule show great strength, running commonly from 60 to 80 pounds, or in some cases 100 pounds, per square inch. The fire clays of the Carboniferous may also show a wide variation. The Pleistocene clays found in the drift regions of the Northeastern States often have great tensile power, and the

[a] Often more.

same is true of many of the sedimentary clays found in river bottoms in various parts of the country.

The tensile strength of clays is usually tested by making them up into briquettes of the same size and shape as those made for testing the tensile strength of cement. They are then thoroughly air dried in a warm room and broken in the machine. Such tests should be made with great care in order to obtain uniform and accurate results, for if the experiments are improperly made the results obtained will be misleading and incorrect.

Plasticity.—This is the property of forming a pasty mass when mixed with water, so that the clay can be molded into any form, which it retains when dried and burned. The plasticity seems to depend more on the physical than on the chemical composition of the clay. The purest clays are by no means the most plastic ones, and the high-grade kaolins, such as those mined in North Carolina and Pennsylvania or those imported from England, are always very lean. The sedimentary clays are in many cases much more plastic than the residual clays, the natural washing process which they have undergone seeming to have increased their plasticity.[a] Many shales, on being ground and mixed with water, will make a plastic mass, but they are on the whole not so plastic as soft surface sedimentary clays. This may be due to the fact that the grains are not always consolidated by mere pressure alone, but may be slightly cemented, so that the grinding does not thoroughly disintegrate the mass. If two samples of the same shale be disintegrated, the one by grinding and the other by exposure to the weather, the latter will usually show more plasticity when they are mixed with water.

Fineness of grain seems to have more or less to do with the plasticity of a clay, so that an increase in its sandiness decreases the plasticity, and consequently clays that are too plastic or fat to work may often be made more easily workable by the addition of sand. Care should always be taken, however, not to add too much of this material to the clay, since an excess of it diminishes its density when burned, and produces a brick or other clay product which is porous and more or less unsound.

Changes in burning.—The shrinkage of the clay in firing has already been referred to. A second change which takes place in the burning of the clay is its densification, for as the clay shrinks in the kiln the particles draw closer and closer together, and the mass becomes more and more dense, reaching at last a condition of impermeability. This nonabsorbent condition is not attained, however, by a mere drawing together of the particles, but is aided by their softening under the action of heat, and by the weight of the clay pressing them together, so that they pack into a solid mass. When the clay has reached this condition in burning, it is

[a] Prof. G. H. Cook found that the plasticity of many lean clays is increased when they are ground, by reason of the breaking up of bunches of minerals, especially kaolinite, that they contain.

said to have been vitrified. Before this point is reached the clay particles soften sufficiently to stick together, but not to crush out of shape, and this stage is known as that of incipient fusion. Most common bricks are burned to this latter point, while paving bricks, sewer pipe, and stoneware are vitrified. If a clay is heated beyond the condition of vitrification, it becomes softer and softer until a temperature is reached at which the clay flows or becomes viscous.

The difference in temperature between the points of incipient fusion and viscosity varies in different clays. In calcareous clays the softening action takes place rapidly and the two extremes may not be more than 50° or 100° F. apart, but in non-calcareous clays the points of incipient fusion and vitrification may be separated by an interval of 400° F. Though the above-named three stages in the burning of the clay are recognized, it is sometimes rather difficult to determine them exactly. The recognition of this difference between the temperatures of incipient fusion and viscosity has a practical value. It is necessary to vitrify many clay products, but when a kiln full is being burned it is not possible to stop the rising temperature within the space of a few degrees, consequently if the difference between the temperature of vitrification and that of viscosity is great it is safe to burn the kiln of ware up to the vitrified stage, and even a little beyond it, without danger of rendering the whole mass viscous.

Fusibility.—The fusibility of clay may depend on the amount of fluxes or fluxing elements, such as lime, magnesia, iron oxide, and alkalies, the size of the clay grain, and also the conditions of the firing, whether oxidizing or reducing. With other things equal the temperature of fusion will fall with an increase in the percentage of fluxing impurities which the clay contains. Fine-grained clays will, other things being equal, usually fuse at a lower temperature than coarse-grained ones. Common brick clays will often fuse at a temperature of from 2,000° to 2,300° F. Stoneware clays can often be heated to a temperature of 2,600° or 2,700° F. before becoming viscous, while good fire clays do not become viscous until 3,200° or 3,300° F., or even more, is reached. The temperature of fusion may be determined in several different ways. One method consists in using test pieces of known composition and consequently known fusibility. Such a set, which is much used by practical clay workers, is known as Seger cones. They are made up of a series of mixtures of clay and fluxes so compounded and graded as to represent a succession of fusion points, each being but a few degrees higher than the preceding. The ingredients of these cones are kaolin, feldspar, quartz, marble, and pure ferric oxide. The series consists of 58 members, the lowest one having a fusion point of 1,094° F. (590° C.), and the highest 3,362° F. (1,850° C.). In order to test the heat of a kiln these cones are placed in the fire at a point where the flame will not strike them. As the heat rises the cones begin to soften, and when the fusing point is reached each bends over until

its tip touches its base. The cones are placed in the kiln at a point where they can be watched through a peephole. Several cones of the several members are put in, for example, 05, 1, and 5. If cones 05 and 1 are melted in the burning, but 5 is not affected, it indicates that the temperature was between 1 and 5. In the next burning 2, 3, and 4 are put in; 2 and 3 may be fused but 4 remain unaffected, showing that the temperature of the kiln was the same as the fusing point of cone 3.

Since these cones are being used very much and are rapidly increasing in favor, it seems desirable to give here the fusion points of the series and also their composition.

Composition and fusing points of Seger cones.

No. of cone.	Composition.	Fusing point.	
		°F.	°C.
.022	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}$ ---------- $\left\{\begin{matrix}2.0\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,094	590
.021	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.1\ Al_2O_3 \left\{\begin{matrix}2.2\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,148	620
.020	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.2\ Al_2O_3 \left\{\begin{matrix}2.4\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,202	650
.019	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.3\ Al_2O_3 \left\{\begin{matrix}2.6\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,256	680
.018	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.4\ Al_2O_3 \left\{\begin{matrix}2.8\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,310	710
.017	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.5\ Al_2O_3 \left\{\begin{matrix}3.0\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,364	740
.016	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.55\ Al_2O_3 \left\{\begin{matrix}3.1\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,418	770
.015	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.6\ Al_2O_3 \left\{\begin{matrix}3.2\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,472	800
.014	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.65\ Al_2O_3 \left\{\begin{matrix}3.3\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,526	830
.013	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.7\ Al_2O_3 \left\{\begin{matrix}3.4\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,580	860
.012	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.75\ Al_2O_3 \left\{\begin{matrix}3.5\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,634	890
.011	$\left\{\begin{matrix}0.5\ Na_2O\\0.5\ PbO\end{matrix}\right\}0.8\ Al_2O_3 \left\{\begin{matrix}3.6\ SiO_2\\1.0\ B_2O_3\end{matrix}\right\}$	1,688	920
.010	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.2\ Fe_2O_3 \left\{\begin{matrix}3.50\ SiO_2\\0.50\ B_2O_3\end{matrix}\right\}$	1,742	950
.09	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.2\ Fe_2O_3 \left\{\begin{matrix}3.55\ SiO_2\\0.45\ B_2O_3\end{matrix}\right\}$	1,778	970
.08	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.2\ Fe_2O_3 \left\{\begin{matrix}3.60\ SiO_2\\0.40\ B_2O_3\end{matrix}\right\}$	1,814	990
.07	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.2\ Fe_2O_3 \left\{\begin{matrix}3.65\ SiO_2\\0.35\ B_2O_3\end{matrix}\right\}$	1,850	1,010
.06	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.2\ Fe_2O_3 \left\{\begin{matrix}3.70\ SiO_2\\0.30\ B_2O_3\end{matrix}\right\}$	1,886	1,030
.05	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.2\ Fe_2O_3 \left\{\begin{matrix}3.75\ SiO_2\\0.25\ B_2O_3\end{matrix}\right\}$	1,922	1,050

Composition and fusing points of Seger cones—Continued.

No. of cone.	Composition.	Fusing point.	
		°F.	°C.
.04	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.2\ Fe_2O_3 \\ 0.3\ Al_2O_3\end{matrix}\right\}\left\{\begin{matrix}3.80\ SiO_2 \\ 0.20\ B_2O_3\end{matrix}\right\}$	1,958	1,070
.03	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.2\ Fe_2O_3 \\ 0.3\ Al_2O_3\end{matrix}\right\}\left\{\begin{matrix}3.85\ SiO_2 \\ 0.15\ B_2O_3\end{matrix}\right\}$	1,994	1,090
.02	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.2\ Fe_2O_3 \\ 0.3\ Al_2O_3\end{matrix}\right\}\left\{\begin{matrix}3.90\ SiO_2 \\ 0.10\ B_2O_3\end{matrix}\right\}$	2,030	1,110
.01	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.2\ Fe_2O_3 \\ 0.3\ Al_2O_3\end{matrix}\right\}\left\{\begin{matrix}3.95\ SiO_2 \\ 0.05\ B_2O_3\end{matrix}\right\}$	2,066	1,130
1	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.2\ Fe_2O_3 \\ 0.3\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2,102	1,150
2	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.2\ Fe_2O_3 \\ 0.4\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2,138	1,170
3	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.05\ Fe_2O_3 \\ 0.45\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2,174	1,190
4	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}0.5\ Al_2O_3 4SiO_2$	2,210	1,210
5	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}0.5\ Al_2O_3 5SiO_2$	2,246	1,230
6	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}0.6\ Al_2O_3 6SiO_2$	2,282	1,250
7	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}0.7\ Al_2O_3 7SiO_2$	2,318	1,270
8	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}0.8\ Al_2O_3 8SiO_2$	2,354	1,290
9	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}0.9\ Al_2O_3 9SiO_2$	2,390	1,310
10	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}1.0\ Al_2O_3 10SiO_2$	2,426	1,330
11	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}1.2\ Al_2O_3 12SiO_2$	2,462	1,350
12	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}1.4\ Al_2O_3 14SiO_2$	2,498	1,370
13	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}1.6\ Al_2O_3 16SiO_2$	2,534	1,390
14	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}1.8\ Al_2O_3 18SiO_2$	2,570	1,410
15	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}2.1\ Al_2O_3 21SiO_2$	2,606	1,430
16	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}2.4\ Al_2O_3 24SiO_2$	2,642	1,450
17	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}2.7\ Al_2O_3 27SiO_2$	2,678	1,470
18	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}3.1\ Al_2O_3 31SiO_2$	2,714	1,490
19	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}3.5\ Al_2O_3 35SiO_2$	2,750	1,510
20	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}3.9\ Al_2O_3 39SiO_2$	2,786	1,530
21	$\left\{\begin{matrix}0.3\ K_2O \\ 0.7\ CaO\end{matrix}\right\}4.4\ Al_2O_3 44SiO_2$	2,822	1,550

Composition and fusing points of Seger cones—Continued.

No. of cone.	Composition.	Fusing point.	
		°F.	°C.
22	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}$ 4.9 Al_2O_3 49 SiO_2	2,858	1,570
23	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}$ 5.4 Al_2O_3 54 SiO_2	2,894	1,590
24	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}$ 6.0 Al_2O_3 60 SiO_2	2,930	1,610
25	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}$ 6.6 Al_2O_3 66 SiO_2	2,966	1,630
26	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}$ 7.2 Al_2O_3 72 SiO_2	3,002	1,650
27	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}$ 20 Al_2O_3 200 SiO_2	3,038	1,670
28	Al_2O_3 10 SiO_2	3,074	1,690
29	Al_2O_3 8 SiO_2	3,110	1,710
30	Al_2O_3 6 SiO_2	3,146	1,730
31	Al_2O_3 5 SiO_2	3,182	1,750
32	Al_2O_3 4 SiO_2	3,218	1,770
33	Al_2O_3 3 SiO_2	3,254	1,790
34	Al_2O_3 2.5 SiO_2	3,290	1,810
35	Al_2O_3 2 SiO_2	3,326	1,830
36	Al_2O_3 1.5 SiO_2	3,362	1,850

For the burning of common bricks the temperatures reached will range from cone 05 to 01; for hollow ware 05 or 01 is probably reached in most cases. In burning paving brick the temperature may range from cone 1 to cone 3; for terra cotta most manufacturers burn from cone 5 to cone 7, unless calcareous clays or impure shales are used, when the temperature would be much lower, ranging from perhaps cone 03 to 1 or 2. In the manufacture of white earthenware the biscuit is commonly burned at from cone 6 to cone 8. In fire-brick manufacture it ranges from cone 10 to cone 14.

A second means of measuring the temperature of the kiln is the thermoelectric pyrometer, which measures a current generated by the heating of a thermopile.[a] The latter consists of two wires, one of platinum and the other of rhodium and platinum, which are soldered together at one end, while they are isolated by being inserted in two fire-clay tubes. The two wires connect with a galvanometer, the declination of whose needle increases with the temperature at the end of the wires. In order to measure the temperature of the kiln, the tubes carrying the wires are put in the kiln either at the beginning of the burning or during the firing. Such a machine, while expensive, is very accurate and is used to a considerable extent by probably at least eighteen clay-working firms in the United States.

[a] Barus, Carl, On the thermo-electric measurement of high temperatures: Bull. U. S. Geol. Survey No. 54.

Color.—The color of a clay is not always an indication of its quality. Many clays are so brilliantly colored with iron—for example, the residual clays of the south—that the color at once indicates their nonrefractory character. When the color, however, is due to carbonaceous or organic matter it is less easy to tell what the color-burning qualities of the clay in question are.

Many black clays burn pure white or cream white. On the other hand, some black clays may burn red, in which case the organic matter masks the presence of the iron. Aside from increasing the shrinkage of the clay, and probably also its absorptive capacity for water, the organic matter exerts little effect on the material. Clays which contain large quantities of it have to be burned rather slowly in order to get it out of the pores of the mass before the clay begins to shrink and vitrify.

Slaking.—The slaking quality of the clay refers to its property of falling apart or disintegrating when thrown into water. Clays which disintegrate rapidly can be mixed up readily, and can be easily washed in case they have to be freed from impurities by mechanical means. Clays which are dense slake very slowly. Many shales will not slake when thrown into water, but exposed to the slow disintegrating action of the weather they fall to pieces slowly but completely.

CHEMICAL PROPERTIES OF CLAY.

The ordinary quantitative analysis, as carried out on clays, shows the quantity of silica, alumina, iron oxide, lime, magnesia, potash, and soda which they contain. In addition to these, there may also be titanic acid, manganese oxide, phosphoric acid, and sulphuric acid, but these four are rarely determined in the ordinary chemical analysis, since they are usually present in but small amounts. The practical clay worker usually considers a physical test far more valuable than a chemical analysis, for the reason that the facts contained in the former are easily capable of interpretation, while those of the latter can not as a rule be utilized by him. While a chemical analysis is always valuable if capable of proper interpretation, it is more so in the case of high-grade than in low-grade clays.

All the constituents which are determined by ordinary chemical analysis influence the fusibility of clay, by either decreasing or increasing it, and consequently such constituents are sometimes grouped as fluxing and nonfluxing ones. Clay containing only kaolinite, the hydrated silicate of alumina, is very refractory, but its fire-resisting qualities may be decreased by addition of any of the fluxes or fluxing impurities, such as iron, lime, magnesia, alkalies. It may therefore be well to refer briefly to the effect of the different elements individually, and also to their sources.

Alkalies.—These include potash and soda, which are present in nearly all clays. They have usually been derived from feldspar or mica, both of which are present in at least small quantity if not in larger amounts. Other minerals, such as garnet,

hornblende, and pyroxene, may also yield these elements. The alkalies found in kaolins probably come from feldspar and white mica, while those found in the residual clays have been partly derived from the iron-bearing minerals, such as garnet, hornblende, and pyroxene. If the alkalies are present in the clay as an ingredient of feldspar grains, they form a desirable fluxing material, and it is on this account that much feldspar is added to kaolin in the manufacture of porcelain, white earthenware, and other wares having a white, dense body. The alkalies probably do not exert any influence on the color of the burned ware.

Ferric oxide.—This may serve either as a flux or as a coloring agent. Its rôle as the latter is mentioned in another part of the paper. Very few clays are free from iron—indeed, it is present in large quantities in some, such as ocher. The residual clays of the Southern States owe their brilliant shades to this coloring material. It also gives the red or brownish colors to many of the shales which are used in the manufacture of paving brick. In fact, it may color a clay or shale red, yellow, brown, or even bluish gray, and sometimes green, according to the compound of iron which is present. Iron is a widespread ingredient of clays, partly because it can be derived from such a large number of minerals. As found in clays, it is present probably in the form of one of the oxides, such as limonite or hematite, or sometimes it may be present as a silicate or even a carbonate. In not a few cases it is found in the clay in the form of a sulphide, as in the mineral pyrite, but its presence is then easily recognized by the fact that it forms yellow metallic grains or bunches, which in black or bluish-black clays are often associated with the lumps of lignite that the deposits contain. Pyrite may cause considerable trouble in the treatment of the clay, for in burning it gives off sulphuric acid, which may make the ware poor, or if present in the clay in little lumps, and these are not extracted or crushed in the preparation of the clay, the lumps will tend to melt and swell up during the burning and split off pieces of the ware. When iron is present in the form of a carbonate or the mineral siderite, it often forms round, stony, or concretionary masses, which are sometimes known as carbonate ore. These are abundant in many of the Carboniferous shales of eastern Ohio and Kentucky, and are present in not a few of the Carboniferous shales of Michigan. They also occur in the Potomac clays in some States.[a] In the mining of the clay these iron-carbonate concretions are usually thrown out. Some clays contain iron in the form of the phosphate, as the mineral vivianite, which is most easily recognized by the presence of blue specks or lumps which it forms.

Whatever iron compound is present in the green clay during the process of burning will be converted into the ferric condition, provided the atmosphere of the kiln is oxidizing—that is, clear and free from smoke; and later in the burning, when the

[a] Ries, H., The clays of Maryland: Maryland Geol. Survey, Vol IV, p. 224.

clay softens or begins to melt, the iron unites with the silica and other elements in the clay and forms a complex silicate. In addition to affecting the fusibility of the clay the iron also colors the burned ware, a small quantity of iron yielding a buff color, a larger quantity a red tint; and the shade produced in any case deepens with higher firing. If lime is present in the clay in excess of the iron the red coloring of the latter will be destroyed and a buff color will be produced instead. It is for this reason that calcareous clays burn to a white or creamy tint.

Lime.—Most clays contain this compound, but certain types are peculiarly rich in it. These are the drift clays of the Northern States and the lake clays of the same region, as well as many of the Paleozoic shales, especially those of the Cambrian and Silurian formations. The residual clays of the Southern States and most of the clay deposits of the Coastal Plain region, with the exception of those of Tertiary age, are usually very low in lime. Calcareous shales may form residual clays low in lime, because during weathering the latter is usually leached out. Lime in clay is commonly derived from the minerals calcite and dolomite, and in rare cases from certain species of feldspar, hornblende, or garnet. Lime, whatever its form, serves as a flux in burning and, as has already been pointed out, tends to destroy the red iron coloration. It also increases the rate of softening of the clay under fire, and consequently, as explained on another page, calcareous clays are undesirable for the manufacture of vitrified ware. The presence of calcium carbonate in a clay can usually be detected by putting a few drops of muriatic acid on it. The effect of the presence of carbonate of lime depends somewhat on the manner of its occurrence or distribution in the clay. Where present in a very finely divided condition it is much less injurious than if it were scattered through the clay in the form of lumps or pebbles. In burning, carbonate of lime is apt to cause difficulty on account of the expulsion of the carbonic acid gas it contains, which forms blisters on the surface of the ware. If present in the form of lumps or pebbles, these may absorb moisture after the brick is burned, and slake, thereby splitting the product. Good bricks can be made from clays containing 20 per cent or more of carbonate of lime, provided it is in a finely divided condition. Calcareous clays are often used in the manufacture of common brick and also for making common earthenware, drain tile, and, less often, terra cotta. They are not suitable for the manufacture of paving brick, stoneware, or sewer pipe. Many such clays are now being used for the manufacture of Portland cement. In addition to affecting the color and fusibility of the clay, lime may also decrease the fire shrinkage.

Magnesia.—With the exception of a variety known as fuller's earth, very few clays contain magnesia in large quantities. As far as known, its action seems to be similar to that of carbonate of lime.

Silica.—The silica present in clay may be of three different kinds, namely: (1) Quartz, (2) that which is combined with alumina and water in kaolinite, and

(3) that which is combined with one or more bases in the silicate minerals, such as feldspar, hornblende, or garnet. In the ordinary chemical analysis the first and third are sometimes placed together under the head of sand, or often incorrectly termed free silica. The silica included under the term sand is practically insoluble in caustic soda and sulphuric acid. There are probably no clays which are perfectly free from quartz, although the amount which they contain may sometimes be very small. Quartz acts as a flux at high temperatures, but at low temperatures it acts as a refractory agent.[a] It also serves to decrease the fire shrinkage and the plasticity of the clay. It may also increase the porosity of the burned ware.

Titanic acid.—This mineral is no doubt widely spread in clays, but is seldom determined in the ordinary chemical analysis. In small amounts it does not seem to exert any effect on the pyrometric characters of the material. Clay never contains enough of it to warrant its extraction.[b]

Organic matter.—This affects not only the color of the clay, but possibly its plasticity and no doubt its absorptive power. It is contained in the clay in the form of very finely divided plant tissue or larger portions of plants or leaves which have settled in the material during its deposition. The color of many of the Carboniferous shales and also of the Cretaceous clays is due to the organic matter which they contain.

Water in clay.—Clays contain two kinds of water, namely, hygroscopic moisture and chemically combined water. Moisture is the water mechanically mixed with the clay grains, and in clays freshly taken from the bank is often as high as 30 or 40 per cent. Shales contain but a small percentage of moisture. The air drying usually causes the evaporation of most of the mechanically combined water, and its expulsion is accompanied by a shrinkage of the mass. It ceases, however, before all the moisture has passed off, for the reason that the shrinkage stops when the particles have all come into contact with one another, but there still remain in the mass pores which hold a certain amount of moisture that is not driven off until the early stages of burning. Moisture may exert a very injurious effect on clays, in that it tends to dissolve the soluble salts which they sometimes contain and to bring them to the surface during air drying, thus forming a scum or efflorescence. If driven off too fast during the early stages of the burning a blistering of the ware may follow.

Combined water is present in every clay, there being nearly 14 per cent in pure kaolin and as low as 2 to 3 per cent in some impure or sandy clays. The sources of combined water in clays are dry kaolinite, limonite, or hydrated silicates. The combined water is driven off at a red heat, and when this occurs an additional shrinkage of the mass takes place.

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[a] The Collected Writings of H. A. Seger, Vol. I, p. 537.

[b] See analyses of fire clays given under Pennsylvania and New Jersey

METHODS OF MINING CLAYS AND SHALES.

The methods employed for mining clay or shale are in most cases essentially the same. When the deposit is of great thickness and extent and the quality of the clay throughout the bank is the same the extraction of the material is very simple and can be accomplished more cheaply and more quickly than if the clay deposit is of small extent or contains a number of varieties of clay intermixed.

The methods commonly employed are two—(1) quarrying or open-pit work, and (2) underground working.

PIT WORKING.

If the deposit of clay or shale which immediately underlies the surface is of great extent and the material is to be extracted in large quantities it will be found economical to use a steam shovel for digging the clay. The capacity of such machines is great and their cost of operation is low, provided they can be kept steadily employed. Excavators of this type are much used in some of the large shale and clay banks of Ohio and Indiana and parts of Pennsylvania, but in other States their use is rather limited. In the States mentioned they are employed chiefly for digging Carboniferous shales, which often form beds of great thickness and horizontal extent. For smaller excavations a custom more commonly followed is to dig the clay by means of pick and shovel. This is done at those yards where the operations are not on a sufficiently large scale to warrant the installment of a steam shovel, and also in those deposits where the clays vary in character in different parts of the bank and can not be mixed in the mining, as would necessarily follow from the use of a steam shovel. This is the method of excavation employed at probably the majority of clay-working plants in the United States. It is employed in most of the Coastal Plain deposits and in the drift clays of the Northern States. Some surface clays are dug with a wheel scraper, a method which is advantageous provided the clay is not too tough.

A modification of the open-pit method is employed in the case of kaolin deposits, which commonly occur in the form of veins. In these deposits circular pits are often sunk to a depth of 50, 60, or more feet, and lined with a temporary crib work. When the kaolin is all worked out the pit is filled, the cribbing being taken out as the filling proceeds. When the entire pit is filled a second circular pit is sunk next to the first one, and the process is thus continued until the whole vein is worked out. The clay is hoisted from the pit in large buckets.

In cases where the clay has to be washed, and is of a very sandy and open character, it is sometimes possible to flood the pit with water, and with a combination scraper and pump to loosen up the clay and carry it up to the works through a pipe.

In not a few regions the clay is found forming banks or terraces along the sides of a valley, and the clay-working plant is often located at the base of the bank. At

some of these localities the undermining system is adopted. In this method the clay is undermined at the base of the bank to a distance of several feet, and wedges are driven into the top of the bank several feet from its front edge, thus prying off large masses, which break in falling.

UNDERGROUND MINING.

Where the desposit of shale does not immediately underlie the surface, but is covered by many feet of other beds of rock, the stripping of the overlying layers would become too costly, and consequently underground methods of mining are adopted. If a bed of shale or clay outcrops at the surface, the usual method is to run a drift or slope in along the clay bed, while from this drift gangways radiate outward in different directions along the line of the deposit, the method of mining being somewhat similar to that followed in the case of coal. Where the clay does not outcrop at the surface it is usually necessary to sink a shaft to the bed, and to run levels from this shaft in different directions into different parts of the clay or shale stratum. In many cases the shaft sunk may encounter more than one bed of clay, so that several deposits can all be mined at the same time. Some of the Carboniferous clay or shale deposits often underlie coal seams, and in such cases the coal also is mined and not infrequently is used as fuel at the brickworks. In rare instances the shale beds have been so upfolded that their dip is nearly vertical, and it is then possible to mine out the shale without removing the rocks that are interbedded with it.

After it is mined the clay is loaded into barrows, carts, or tram cars and hauled to the works. Where the quantity extracted is comparatively small and the lead is very short, the most profitable method is to use wheelbarrows. Where the output is large, cars drawn by horses or tram cars run on a temporary track are found to be the most suitable. Where the scale of operations is large, steam haulage is preferable, and this is commonly employed where the factory is some distance from the bank and the quantity of the clay to be hauled is considerable. A very few factories in this country transport their clay from the bank to the plant by means of a wire-rope tramway; this method of haulage is frequently employed abroad.

PURIFICATION OF CLAY.

Many clays, as they come from the bank or mines, contain mineral impurities which it is undersirable to retain in the clay, and means are therefore often taken to remove them. These methods of purification are not often applied to low-grade clay, for the reason that they would increase the expense of manufacture too much, and they are consequently confined chiefly to the better grades of raw material. The two methods commonly employed for cleansing clays are screening and washing. Clays are often screened to free them from limestone pebbles or lumps of pyrite or other stony

matter whose presence is undesirable. As the injurious effect of these substances can often be greatly lessened by reducing them to a finely divided condition, it is not uncommon to crush the material rather than to screen it, for the screening process usually necessitates previous drying.

WASHING.

Clays employed for the manufacture of pottery are usually washed. The process of washing consists in disintegrating the clay, either in troughs by rotating knives or by slaking it in water and then exposing it to a current. This operation effects a mechanical separation of the material—the finer grains of clay, on account of their lightness, being carried off to settling tanks, while the coarse, sandy particles and pebbles, on account of their greater weight, fall to the bottom of the washing troughs.

Low-grade clays are rarely washed in the United States, but abroad the simple washing process is often used to free the clay from an excess of sand.

Following is a description of the washing process:[a]

"Clays are washed by one of two methods. With the first method, the clay is thrown into large circular tubs filled with water, in which it is stirred up by revolving arms, and the clay lumps are thereby disintegrated. By this treatment the fine kaolinite particles, as well as very fine grains of mica, feldspar, and quartz, remain suspended in the liquid, while the coarser grains settle in the bottom of the tank. The water with the suspended clay is then drawn off to the settling tanks.

"A modification of this consists in the use of a large cylinder, closed at both ends, which is set in a horizontal position, and contains an axis with iron arms, their revolution serving to break up the clay, which is charged through a hopper at the top. A current of water passes through the cylinder and carries the fine clay particles with it, while the coarse ones are left behind in the machine. The speed of the current has to be regulated by experiment, for if too much water is used coarse material will be washed out of the cylinder, and, conversely, if the current is too slow the clay will not yield a sufficient percentage of washed product. One objection to this apparatus is that it has to be stopped from time to time to remove the coarse sand from the machine.

"The method most commonly used at the present day for washing kaolin is in its general detail as follows:

"As the kaolin comes from the mine it is generally discharged into a log washer, a semicylindric trough, in which revolves a horizontal axis bearing short arms. The action of the arms breaks up the kaolin more or less thoroughly, according to its density, and facilitates the subsequent washing. The stream of water directed into the log washer sweeps the kaolin and most of the sand into the washing trough, which is about 15 inches wide and 12 inches deep, but should be wider and deeper if the kaolin is very sandy.

"The troughing has a slight pitch, commonly about 1 inch in 20 feet, but the amount depends on the kaolin and whether the contained sand is fine or coarse. If the

[a] Bull. New York State Museum No. 35, p. 799.

kaolin is very fine and settles slowly, the pitch need not be so great, and vice versa. A large quantity of very coarse sand in the kaolin is a nuisance, as it clogs up the log washer and the upper end of the trough more quickly, causing much labor to keep them clean. As it is, considerable sand settles there, and to keep the trough clear sand wheels are used. The wheels are wooden, bearing a number of iron scoops on their periphery. As the wheels revolve the scoops catch up a portion of the sand which has settled in the trough, and as each scoop reaches the upper limit of its turn on the wheel, by its inverted position, drops the sand outside the trough. These sand wheels are a help, but it is often necessary, in addition, to keep a man shoveling the sand from the trough.

"If the sand is finer it is not dropped so quickly and, distributed more evenly along the trough, does not clog it up so fast.

"The zigzag arrangement of the troughing has been objected to by some, as it produces irregularities in the current, causing the sand to bank up in the corners, at the bends, and at certain points along the sides of the troughing.[a] The effect is to narrow the channel and consequently increase the velocity of the current, thereby causing the fine sand to be carried still farther toward the settling tank. This difficulty, which is not often serious, has been obviated either by having the troughing straight or by allowing the water and suspended clay as they come from the log washer to pass through a section of straight trough, and from this into another of the same depth, but five or six times the width, and divided by several longitudinal partitions. The water and the clay then pass into a third section, twice as wide as the second, and divided by twice the number of longitudinal divisions. By this means the water moves only in a straight course, but as it is being continually spread out over a wider space, it flows with an ever-decreasing velocity.

"By the time the water has reached the end of the troughing nearly all the coarse grains have been dropped and the water is ready to be led into the settling vats, but as a further and necessary precaution it is discharged on a screen of 100 meshes to the linear inch, with the object of removing any coarse particles that might remain, and also of eliminating sticks and other bits of floating dirt.

"Two kinds of screens can be used—the first stationary, the second revolving. The stationary screen is simply a frame covered with a copper cloth and set at a slight angle. The water and suspended kaolin fall on the screen and pass through, otherwise they run off and are lost. A slight improvement is to have two or three screens overlapping one another, so that whatever does not get through the first will fall on the second. If the vegetable matter and sticks are allowed to accumulate they clog the screen and prevent the kaolin from running through, consequently stationary screens must be closely watched.

"The revolving screens are far better, for they are self-cleansing. Such screens are barrel-shaped, and the water, with the kaolin in suspension, is discharged into the interior and passes outward through the screen cloth. As the screen revolves the dirt caught is carried upward and finally drops: but instead of falling down on the other side of the screen it falls on a board, which diverts it out to the ground.

"The settling tanks, into which the kaolin and the water are discharged, may be and often are about 8 feet wide by 4 feet deep and 50 or more feet long. As soon as

[a] Hotop, E., Thonindustrie Zeitung, 1893.

one is filled the water is diverted into another. The larger a tank the longer it will take to fill it and allow the kaolin to settle. Clays obtained in this manner are expensive, particularly when the market takes the output of washed kaolin as soon as it is ready. Small tanks have the advantage of permitting the slip to dry more quickly, especially when the layer of clay is not very thick, furthermore a small pit takes less time to fill and empty. But one disadvantage urged against a number of small tanks is that a thoroughly average product is not obtained, owing to the thinness of the layer of settlings and the small amount in each. In addition, a series of small tanks requires considerable room. The advantages asserted in the case of large tanks are that the clay can be discharged into any one for a considerable period, and if the clay deposit varies in character the different grades get into one tank and a better average is thereby obtained.

"If the kaolin settles too slowly, alum is sometimes added to the water to hasten the deposition. When the kaolin has settled, most of the clear water is drawn off; the cream-like mass of kaolin and water in the bottom of the vat is drawn off by means of slip pumps and forced by these into the presses.

"The presses consist simply of flat iron or wooden frames, between which are flat canvas bags. These bags are connected by nipples with a supply tube from the slip pumps, and by means of the pressure from the pumps nearly all of the water is forced out of the kaolin and through the canvas. When as much water as possible is squeezed out, the press is opened and the sheets of semidry kaolin are taken out. It is then dried either on racks in the open air or in a steam-heated room.

"As for every ton of kaolin usually about two-fifths or one-quarter of a ton of washed kaolin is obtained, it is desirable to have the washing plant at the mines, to avoid the hauling of 60 or 70 per cent of useless sand which has to be washed out before the kaolin can be used or even placed on the market."

AIR SEPARATION.

This is a method of cleansing clays which has been rarely tried, yet in some of the cases where it has been used it is said to have met with success. It is especially applicable to those clays from which it is necessary to remove simply coarse or sandy particles. The process consists, in brief, in feeding the dry clay into a pulverizer which reduces it to the condition of a very fine powder. As the material is discharged from the pulverizer into a long box or tunnel, it is seized by a powerful current of air, which at once picks up the fine particles and carries them along to the end of the airway, where they are dropped into a bin. The coarser particles, which are too heavy to be picked up by the current, drop back and are carried through the pulverizer once more. Such a method would be especially applicable to kaolins that are free from iron, but probably would not be found adaptable to many of those containing ferruginous particles.

There are several forms of separators on the market. In the Raymond pulverizer and separator the material is pulverized in the lower part of the machine and then thrown upward, the finer particles being carried off by a fan to the discharge hopper, the coarser ones falling back into the hopper.

COMMERCIAL VALUE OF CLAY.

Since most clays are manufactured into clay products by the firm mining them, but a small proportion of the total quantity of clay mined is sold. The grades which are sold are usually kaolins, ball clays, fire clays, paper clays, and some pottery and terra-cotta clays. Clays are commonly sold by the ton, the price being quoted either f. o. b. or at the market. Their value ranges from as low as 50 or 75 cents per ton for some pottery and terra-cotta clays up to as high as $10 or $12 per ton for washed kaolins.

The valuation of clay is based on its purity, physical characters, distance from market, size of deposit, and demand. Clays which might be valuable if near transportation lines are often valueless because of their remoteness from railways. Kaolins commonly bring from $10 to $12 per ton, delivered in Trenton, N. J., or East Liverpool, Ohio. Ball clays vary in price. The rate per ton delivered in Trenton would be somewhat as follows: Florida ball clay (washed), $10 per short ton; English ball clay, $8 to $10 per long ton; New Jersey crude, $5 to $6 per long ton; New Jersey washed, $7 to $8; Kentucky and Tennessee clay (washed), slightly more than New Jersey.

Fire clays usually bring from $1 to $2 per ton f. o. b., the average value in 1900 being $1.70 per ton. Many fire clays are sold for pottery and terra-cotta manufacture.

Paper clays vary from $7 to $10 per ton for domestic ones, the value being based on freedom from grit and whiteness of color.

The structure and mode of occurrence are potent factors which must enter into the valuation of any clay bed. Persons unfamiliar with clays are apt to look only at the character of the material itself, giving no attention to the extent and thickness of the deposit, amount of overburden, etc. Many clay deposits in the Cretaceous or Tertiary formations of the Southern States often show a variety of plastic material in the same section, but the different grades are so closely mixed that the amount of labor required to separate them in mining would be so great as to prohibit the sale of the clay.

USES OF CLAY.

The uses of clay can be best shown by the following table, compiled originally by R. T. Hill[a] and amplified by the writer.

Domestic.—Porcelain, white earthenware, stoneware, yellow ware and Rockingham ware for table service and cooking; majolica stoves; polishing brick, bath brick, fire kindlers.

Structural.—Brick, common, front, pressed, ornamental, hollow, glazed, adobe,

[a] Mineral Resources U. S. 1891, p 475.

terra cotta; roofing tile; glazed and encaustic tile; drain tile; paving brick; chimney flues; chimney pots; doorknobs; fireproofing; terra-cotta lumber; copings; fence posts.

Hygienic.—Urinals, closet bowls, sinks, washtubs, bath tubs, pitchers, sewer pipe, ventilating flues, foundation blocks, vitrified bricks.

Decorative.—Ornamental pottery, terra cotta, majolica, garden furniture, tombstones.

Minor uses.—Food adulterant; paint fillers; paper filling; electric insulators; pumps; fulling cloth; scouring soap; packing for horses' feet; chemical apparatus; condensing worms; ink bottles; ultramarine manufacture; emery wheels; playing marbles; battery cups; pins, stilts and spurs for potter's use; shuttle eyes and thread guides; smoking pipes; umbrella stands; pedestals; filter tubes; caster wheels; pump wheels.

Refractory wares.—Crucibles and other assaying apparatus; gas retorts; fire bricks; glass pots; blocks for tank furnaces; saggers; stove and furnace bricks; blocks for fire boxes; tuyeres; cupola bricks.

Engineering works.—Puddle; Portland cement; railroad ballast; water conduits; turbine wheels.

CLAYS EMPLOYED.

Very few of the above materials are made from one grade of clay alone; in fact, probably 90 per cent of the articles mentioned in the above list are molded of a mixture of at least three clays, and many clays are used for several purposes.

The aim of the manufacturer in each case is to get a mixture of the proper plasticity, color-burning qualities, shrinkage, and refractoriness. This is a subject to which much consideration is given in the manufacture of the medium and higher grades of ware, for neglect of these points may cause much loss in burning.

The class of clays employed in the more important kinds of wares mentioned above is as follows:

CHINA CLAYS.[a]

Porcelain, white earthenware, and granite ware are made of a mixture of kaolin, ball clay, feldspar, and quartz, all rendered very fine grained by preliminary washing or grinding.

The clays used must be of the best quality, burning to a white color at the fusing point of cone 8 (about 2,350° F.). This necessitates the selection of a clay of very low ferric-oxide content, preferably under 1 per cent. Good plasticity is also desired, and is supplied by the ball clay. The kaolins and ball clays employed are partly of domestic production and partly imported. The imported ball clays come from England, and vitrify at a much lower temperature.[b]

[a] For distribution see Pl. IX, p. 284.

[b] For analyses and tests of kaolins and ball clays see Alabama, North Carolina, Florida, Pennsylvania, Delaware, and Tennessee. Also Ries, H., The pottery industry of the United States: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. III (continued), p. 842.

The following physical tests will give some idea of the character of the materials used:

KAOLIN.

Harris Clay Company, Webster, N. C.—Works up with 42 per cent of water to a lean mass. Air shrinkage, 6 per cent; fire shrinkage, 4 per cent, making a total of 10 per cent. Average tensile strength, 20 pounds per square inch, with a maximum of 22. Incipient fusion, 2,300° F.; vitrification at 2,500°; viscosity above 2,700°. Burns white.[a]

Arnold land, Thayer, Davidson County, N. C.—Works up with 23 per cent water to a lean mass, whose air shrinkage is 3.2 per cent and fire shrinkage 3.3 per cent, giving a total of 6.5 per cent. Average tensile strength per square inch, 13 pounds; maximum, 14 pounds. Incipient fusion at 2,300° F.; complete fusion at 2,600°; viscosity at 2,700°. Total per cent of fluxes, 2.36.[a]

Glen Allen, Mo.—Requires 23.2 per cent water to work it up to a lean paste, whose air shrinkage is 4 per cent and fire shrinkage 8.4 per cent, making a total shrinkage of 12.4 per cent. Average tensile strength per square inch, 12 pounds; maximum, 14 pounds. Incipient fusion at 2,200° F.; vitrification at 2,500°; viscosity not given.

BALL CLAYS.

Regina, Jefferson County, Mo.—With 22.7 per cent of water it worked up to a very plastic mass, whose air shrinkage was 7.7 per cent and fire shrinkage 12.2 per cent, giving a total of 19.9 per cent. Average tensile strength per square inch, 99 pounds; maximum, 108 pounds. Incipient fusion at 1,800° F.; vitrification at 2,100°, and viscosity at 2,400°. Total fluxes, 5.15 per cent.[b]

Edgar, Fla.—Very plastic and has an average tensile strength of about 65 pounds per square inch. Incipient fusion at 1,800° F.; vitrification at 2,100°, and viscosity at 2,400°. Total fluxes, 5.15 per cent.[c]

South Amboy district, New Jersey.—When burned at cones 8 and 9 is of a yellowish-white color, and shows a total shrinkage of 14 per cent. This is rather plastic, but has a low tensile strength.

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[a] Bull. North Carolina Geol. Survey No. 13, p. 59.
[b] Missouri Geol. Survey, Vol. XI, p. 578.
[c] Langenbeck, Chemistry of Pottery, p. 101.

The following table gives the composition of several American ball clays and kaolins, as well as of the English clay, the latter being added for purposes of comparison:

Analyses of ball clays.

	1.	2.	3.	4.	5.	6.
SiO_2	46.11	44.40	44.89	56.40	48.99	59.61
Al_2O_3	39.55	38.34	37.269	30.00	32.11	26.81
FeO					2.34	2.03
Fe_2O_3	.35	.86	.97			
CaO			.41	.40	.43	.82
MgO	.13		.19	Tr.	.22	.44
Na_2O		.18	1.124	2.01		
K_2O		.26	.317	3.26	3.31	3.57
H_2O	13.78	13.50	14.47	7.93	9.63	7.46
SO_3	.07					
TiO_2	1.20					
Moist		1.10				2.33

1, Edgar, Fla.; 2, Burts Creek, N. J.; 3, South Amboy, N. J.; 4, Mayfield, Ky.; 5 and 6, "Poole" clay from Wareham, England.

Analyses of washed kaolins.

	1.	2.	3.	4.	5.	6.	7.	8.
SiO_2	46.278	45.70	46.50	50.96	48.26	47.71	46.87	59.42
Al_2O_3	36.25	40.61	37.40	33.30	37.64	36.78	38.00	27.15
Fe_2O_3	1.644	1.39	.80	.82	.46		.89	1.77
CaO	.192	.45	Tr.		.06		Tr.	
MgO	.321	.09		2.42	Tr.		.35	.52
Alkalies	2.536	2.82	1.1		1.56	2.58	1.22	[a]1.50
H_2O	13.535	8.98	12.49	8.95	12.02	13.03	12.70	9.85

[a] All K_2O.

1. Brandywine Summit, Pa.
2. Harris Clay Company, near Webster, N. C.
3. West Cornwall, Conn.
4. Glen Loch, Pa.
5. Cornwall, England.
6. Coussac-Bonneval, France.
7. Zettlitz, Bohemia.
8. Pilsen, Bohemia.

FIRE CLAYS.

Fire bricks, crucibles, and similar wares are made from clays whose main requisite is refractoriness, although plasticity is also needed. Consequently mixtures of several different clays must be made for the best results. A clay to be considered

refractory should not fuse under 3,000° F. (cone 27). The following analyses show the composition of several standard American fire clays:

Analyses of fire clays.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
SiO_2	74.25	63.00	52.52	59.92	57.80	61.75	51.92	46.90	44.20
Al_2O_3	17.25	23.57	31.84	27.56	25.54	23.66	31.64	35.90	38.66
FeO	.....	.46	.....	.....	.....	1.93	1.134	.....	.....
Fe_2O_3	1.19	1.87	.67	1.03	2.51	.....	.....	1.10	.74
CaO	.40	.44	.50	Tr.	.25	.455	.03	.....	.....
MgO	Tr.	.89	.19	Tr.	.61	.353	.443	.....	.....
Alkalies	.52	2.69	.59	.67	2.69	2.418	.402	.44	.46
TiO_2	.....	1.10	1.68	.....	.....	1.78	1.16	1.30	1.20
H_2O	6.30	6.45	11.68	9.70	8.35	7.20	13.49	12.80	13.55

1. Bibbville, Ala.
2. Mecca, Parke County, Ind.
3. Mineral Point, Ohio (flint clay).
4. Salineville, Ohio (flint clay).
5. East Palestine, Ohio.
6. New Brighton, Pa.
7. Salina, Pa.
8. Woodbridge, N. J.
9. Sayreville, N. J.

There are several special grades of fire clay whose value depends on other properties than refractoriness. These are glass-pot and zinc-retort clays.

GLASS-POT CLAYS.

The manufacture of glass pots calls for a clay which is not only refractory, but burns dense at a moderately low temperature, so that it will resist the fluxing action of the molten glass. It must possess good bonding power and burn without warping. Great care is necessary in the selection of the clay and the manufacture of the pot.[a]

Most of the glass-pot clay used in the United States is imported from Germany, but in recent years much clay from Missouri, and a smaller quantity from Pennsylvania, have been used to mix with the imported material. In the following table is the analysis of a Pennsylvania glass-pot clay:

[a] For discussion of manufacture see Orton, E., jr., Report on the clays of Ohio: Ohio Geol. Survey, Vol. VII, part 1; Ries, H., The clays of New York: Bull. New York State Museum No. 35, p. 786.

Analysis of glass-pot clays from Layton station, Pa.

	Per cent.
SiO_2	64.89
Al_2O_3	24.08
Fe_2O_3	.29
FeO	.21
CaO	.41
MgO	.19
Alkalies	1.03
H_2O	9.29
Total	100.39

STONEWARE CLAYS.

Stoneware is commonly made of a semirefractory clay, which burns dense and holds its form well in burning. The clays may often show high plasticity and tensile strength (often 150 to 200 pounds per square inch), and not uncommonly burn buff. This is the type employed in chemical and sanitary apparatus. The physical characters of several stoneware clays are here given:

Waltemers, Barton County, Mo.—With 19.2 per cent of water this works up to a rather lean mass, whose air shrinkage is 5.5 per cent and fire shrinkage 6.1 per cent, giving a total of 11.6 per cent. Average tensile strength per square inch 87 pounds, maximum 98 pounds. Incipient fusion at 2,000° F., vitrification at 2,200°,[a] viscosity at 2,400°. Total fluxes, 2.42 per cent.

Calhoun, Henry County, Mo.—A very plastic, buff-burning clay requiring 16.5 per cent of water to temper it. Air shrinkage 5.5 per cent, fire shrinkage 2.2 per cent, total 7.7 per cent. Average tensile strength per square inch 150 pounds, maximum 168 pounds. Incipient fusion at 2,100° F., vitrification at 2,300°, viscosity at 2,500°. Total fluxes present, 5.04 per cent.[b]

Sammis's pits, Little Neck, near Northport, Long Island, N. Y.—A yellow, sandy clay requiring 25 per cent of water to work it up, and having fair plasticity. Average tensile strength per square inch 25 pounds, maximum 30 pounds. Air shrinkage 5.5 per cent, fire shrinkage 6.5 per cent, giving a total of 12 per cent. At 2,300° F. nearly vitrified, and becoming viscous at cone 27. Burns buff.[c]

Fernbank, Lamar County, Ala.—A very plastic clay which works up with 32.6 per cent of water. Air shrinkage 10 per cent, fire shrinkage 7 per cent, giving a total shrinkage of 17 per cent. Average tensile strength 152 pounds per square inch, maximum 185 pounds. Incipient fusion at 1,900° F., vitrification at 2,100°, viscosity at 2,300°. Clay burns red and has 6.65 per cent total fluxes.[a]

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[a] Missouri Geol. Survey, Vol. XI, p. 575.
[b] Ibid., p. 577.
[c] Bull. New York State Museum No. 35, p. 821.
[a] Bull. Alabama Geol. Survey No. 6, p. 174.

CLAYS FOR VITRIFIED WARES OF LOW GRADE.

Sewer pipe, paving brick, and other vitrified wares of nonrefractory character are made from clays or shales of fine grain, ferruginous composition, and preferably good plasticity and tensile strength. They vitrify usually at a low temperature, cone 2 to 4, have a low fire shrinkage, and burn to a dense red body. In Ohio a mixture of low-grade fire clay and shale is sometimes preferred. The following analyses give the average composition of a number of carefully selected clays used for paving brick:

Analyses of clays used for making paving bricks.[a]

	Minimum.	Maximum.	Average.
Silica	49.00	75.00	56.00
Alumina	11.00	25.00	22.50
Ferric oxide	2.00	9.00	6.70
Lime	.20	3.50	1.20
Magnesia	.10	3.00	1.40
Alkalies	1.00	5.50	3.70
Ignition	3.00	13.00	7.00

[a] Wheeler, Vitrified Paving Brick.

The analyses show that the iron oxide, lime, magnesia, and alkalies are usually rather high.

The following tests of clays and shales obtained from different localities will illustrate fairly well the physical character of the raw materials used in the manufacture of paving brick.

Carboniferous shale from the pit of the Saginaw Clay Manufacturing Company, 1 mile north of Flushing, Mich.—The lower shale layer, or so-called fire clay, requiring 20 per cent of water to work up into a moderately plastic mass with an air shrinkage of 5 per cent. Tensile strength of air-dried briquettes from 60 to 65 pounds per square inch. Incipient fusion at cone 1, with total shrinkage of 10 per cent; at cone 5, shrinkage 11 per cent; vitrification at cone 7; viscosity at cone 11.[a]

Upper shale from the same bank, hard, and sandy in character.—With 20 per cent of water worked up into a lean mass having an air shrinkage of 3 per cent; total shrinkage up to cone 05, 5 per cent, with incipient fusion occurring at cone 1. At this latter point the color was red and the total shrinkage was 7 per cent. Vitrification at cone 6; total shrinkage 9 per cent; viscosity at cone 8. Tensile strength from 35 to 40 pounds per square inch. A mixture of the two shales is used.[a]

Carboniferous shale from Galesburg, Ill.—This requires 28 per cent of water to work up. Air shrinkage, 4 per cent; total shrinkage at cone 03, 10 per cent; vitrifi-

[a] Michigan Geol. Survey, Vol. VIII, Pt. I, p. 32.

cation at cone 2, and viscosity at cone 5. Tensile strength, 60 to 70 pounds per square inch.[a]

Pleistocene clay from Three Rivers, New York.—Requires 28 per cent of water to work it up into a very plastic mass. Air shrinkage, 5 per cent. Incipient fusion at cone 05, with total shrinkage of 7 per cent; vitrification at cone 1, with 11 per cent total shrinkage. Viscosity at cone 3. Tensile strength of briquettes, 60 to 70 pounds per square inch. These figures are probably low.[b]

Paving-brick shale, Coaldale, Ala.—A yellowish-red shale with considerable grit. Mixes up to a lean mass with 22 per cent of water and 4 per cent air shrinkage. Total shrinkage up to vitrification, 9.5 per cent. Tensile strength, 25 to 35 pounds. Incipient fusion, 1,900° F., and viscosity at 2,150° F.[c]

TERRA-COTTA CLAYS.

Terra cotta is made from a great number of different clays, but most manufacturers of this material are now using fire clays, for these give the best results at the temperatures (cone 6-8) attained in their kilns. The color of the body of the burned mixture is usually buff, the exterior or surface color being due to an application of slip to the outside of the ware. A few terra-cotta makers use low-grade red-burning clays or shales. Since the clays that are used in the manufacture of terra cotta are often employed for the manufacture of other grades of clay products, it is not possible to give a table of analyses of what might be strictly called terra-cotta clays, and therefore only four are given in order to show what a wide range of materials is used.[d] These are (1) Devonian shale from Alfred Center, N. Y.; (2) shale from Billings, Mo.; (3) Pleistocene clay from Glens Falls, N. Y.; and (4) Cretaceous clay from Woodbridge, N. J.

Analyses of clay used for the manufacture of terra cotta.

	1.	2.	3.	4.
Silica	53.20	63.11	48.35	44.20
Alumina	23.25	23.11	11.38	38.66
Ferric oxide	10.99	1.79	4.02	.74
Lime	1.01	.42	15.38	.....
Magnesia	.62	.70	3.17	.....
Alkalies	2.69	3.71	6.05	.46
Water	6.39	7.05	.....	13.55
Total	98.15	99.89	.....	97.61

Clay for terra cotta should burn to a hard body at a moderately high temperature, say 2,300° F., producing a nearly impervious product. While it is desirable to

[a] Bull. New York State Museum No. 35, p. 744.
[b] Ibid., p. 757.
[c] Bull. Alabama Geol. Survey No. 6, p. 187.
[d] Mineral Industry, Vol. IX.

have a vitrifiable clay, the burning of the body is seldom carried to this point for the reason that it is accompanied by too much risk of cracking by overshrinkage. Accordingly, it is customary to use a semirefractory clay which is burned to a hard body, but not an impervious one.[a]

BRICK CLAYS.

PRESSED BRICK.

Pressed or ornamental brick are often molded from refractory or semirefractory clays because the buff product thus obtained is very popular, and, furthermore, the buff color makes a good base with which artificial coloring material may be mixed for the production of many other shades. Red clays are still used to some extent, but the demand for them is not nearly as great as formerly.

Whatever the class of clay used for pressed brick, uniformity of shade and freedom from discoloration are essential features of the burned product. The discoloration is due to improper mixing or the presence of soluble compounds in the clay, which form a scum on the surface.[b]

The physical properties of the clay are of much importance. High refractoriness is not essential, but since straightness of outline is called for, clays of low shrinkage are preferred. Excessively plastic material is undesirable where the stiff mud process is employed, but for dry press brick the plastic qualities of the clay do not play so important a rôle.

Clays of streaky character are often avoided unless they mix readily in the machine. Many Coastal Plain clays contain layers of tough whitish-burning clay mixed with ferruginous sandy layers. Imperfect mixing of such a clay shows itself in the brick by the presence of white spots scattered through it.

In the following table are given analyses of pressed-brick clays, showing the range of materials now used:

Analyses of clays used for making pressed brick.

	Shale—Kansas City, Mo.	White clay—Grover, N. C.	Front brick clay—Sayreville, N. J.
Silica	55.75	68.28	56.10
Alumina	21.16	18.83	27.42
Ferric oxide	5.69	2.60	2.68
Lime	3.25	.70	.....
Magnesia	2.84	.13	.18
Alkalies	3.02	2.29	2.71
Water	8.45	6.47	6
Moisture	.....	.76	2.90
Titanic acid	.....	.27	1

[a] For manufacture of terra cotta see Bull. New York State Museum No. 35, p. 761.
[b] Bull. New York State Museum No. 35, p. 681.

COMMON BRICK.

These are made from almost any kind of clay, ranging from the calcareous, pebbly clays found in the regions around the Great Lakes to the impure, ferruginous, residual clays found all over the South. Little care is taken, as a rule, in the manufacture of common brick, although when the clay at hand is too plastic or fat it is customary to lessen its pastiness by the addition of sand. The addition of too great a quantity, however, will make the brick porous and weak.

A clay to be used for the manufacture of common brick should burn red if possible, since there is then more possibility of its burning dense at a comparatively low temperature and thus avoiding the use of too much fuel. Most brick clays are burned to about cone 0.05, and at this temperature the clay commonly shows incipient fusion. Good brick clays should burn hard at a temperature of not over 2,000° F., namely, at cone 1, or preferably lower. This means the presence of sufficient fluxing material to bind the clay grains together into a hard body when burned. Large sand grains and pebbles are undesirable, for they tend to make the product porous and weak. The best results are commonly obtained with clays carrying from 5 to 7 per cent of ferric oxide. The residual limestone clays are often ferruginous, and those derived from gabbros or other dark-colored igneous rocks of the crystalline area are often highly so—too much so, in fact, for the production of really good brick.

The following figures give the maximum, minimum, and average percentage of the different constituents in brick clays, the figures being deduced from a number of analyses from different parts of the country:[a]

Analyses of brick clays.

	Minimum.	Maximum.	Average.
Silica	34.35	90.877	49.27
Alumina	22.14	34	22.77
Ferric oxide	.126	15	5.311
Lime	.024	13.20	2.017
Magnesia	.02	11.03	2.66
Alkalies	.17	15.32	2.768
Water	.05	13.60	5.749
Moisture	.17	9.64	2.505

The following tests indicate the physical character of brick clays:

Pleistocene brick clay from the Hudson Valley at Roseton, N. Y.—Air shrinkage, 5 per cent; incipient fusion at cone 0.05; vitrification at cone 0.04, with a total shrinkage of 14 per cent; viscosity at cone 0.01. Tensile strength, 75 to 93 pounds per square inch.[b]

[a] Bull. New York State Museum No. 35, p. 737.
[b] Ibid., p. 688.

Pleistocene clay from Canandaigua, N. Y., upper layer in bank.—Requires 22 per cent of water to work it up to a plastic mass; air shrinkage, 8 per cent; incipient fusion at cone 0.05, with a total shrinkage of 15 per cent; vitrification at cone 0.03, with total shrinkage of 16 per cent; viscosity at cone 8. Burns red.[a]

Lower or buff-burning clay from same locality.—18.5 per cent water required to temper it. Air shrinkage, 6 per cent; vitrification at cone 1, with 14 per cent shrinkage; viscosity at cone 2. Tensile strength 95 to 110 pounds per square inch.

Brick clay of glacial age, Southold, Suffolk County, N. Y.—A very plastic clay requiring 40 per cent of water. Air shrinkage, 8 per cent. Vitrification at cone 1, with total shrinkage of 16 per cent. Viscosity at cone 4.[b] Clay burns deep red. Tensile strength 133 to 140 pounds per square inch.

Brick clay from Clippert Brothers' yard, Detroit, Mich.—A calcareous clay. Twenty-four per cent of water required to work it up, the briquettes having an air shrinkage of 4 per cent. At cone 0.05 total shrinkage 6 per cent, clay burns red; at cone 0.01 incipient fusion occurs with a total shrinkage of 14 per cent, the bricklet being buff; vitrification occurs at cone 2, and the clay becomes viscous at cone 4. Its tensile strength is 150–190 pounds per square inch.[c]

Lower clay from the same locality.—A very plastic blue clay requiring 26 per cent of water. Incipient fusion occurs at cone 0.05, with a total shrinkage of 9 per cent; vitrification at cone 1, with a total shrinkage of 15 per cent; viscosity at cone 5. Tensile strength, 175 to 190 pounds per square inch. It is found difficult to work this clay alone.

Residual brick clay near Greensboro, N. C.—Twenty-eight per cent of water required to work it up. Air shrinkage, 9 per cent. Total shrinkage up to vitrification, 15 per cent. Average tensile strength, 85 pounds per square inch. Incipient fusion at 2,050° F., vitrification at 2,250°, viscosity at 2,450°. Clay burns red.[d]

An alluvial brick clay from Kirkpatrick's yard, Greensboro, N. C.—Thirty per cent of water works it up into a very plastic mass. Air shrinkage, 11 per cent. Total shrinkage up to vitrification, 16 per cent. Average tensile strength, 220 pounds per square inch; maximum, 232 pounds. Incipient fusion at 1,900° F., vitrification at 2,100°, and viscosity at 2,300°. It burns to a dense red body, but requires slow heating to prevent cracking.[e]

Brick clay, Jefferson City, Mo.—A lean clay, requiring 17.2 per cent of water to temper it. Air shrinkage, 5.7 per cent. Shrinkage in burning, 4.3 per cent. Incipient fusion 2,000° F., vitrification at 2,000°, and viscosity at 2,300°. Average tensile strength, 151 pounds per square inch.[f]

Brick clay, Kansas City, Mo.—18.4 per cent of water required, giving a lean mass. Air shrinkage, 5.1 per cent. Total shrinkage in burning, 10.8 per cent.

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[a] Bull. New York State Museum No. 35, p. 719.
[b] Ibid., p. 737.
[c] Michigan Geol. Survey, Vol. VIII, Pt. 1, p 50.
[d] Bull. North Carolina Geol. Survey No. 13, p. 114.
[e] Ibid., p. 115.
[f] Missouri Geol. Survey, Vol. XI, p. 486.

Incipient fusion at 2,000° F., vitrification at 2,200°, and viscosity at 2,200°. Average tensile strength, 151 pounds per square inch. This is a loessoid clay.[a]

Brick clay (loess) from Denver, Colo.—A lean clay, taking 14.5 per cent of water to work it up. Air shrinkage, 6 per cent; total shrinkage in burning, 9 per cent; air-dried briquettes average tensile strength of 55 pounds per square inch. Incipient fusion at 2,000° F., vitrification at 2,100°, viscosity at 2,200°. Clay burns red.[b]

EARTHENWARE CLAYS.

Many of the smoother surface clays employed in making common brick are also found satisfactory for the manufacture of earthenware. The materials needed are such as will form a mass of good plasticity with water, will turn readily on the potter's wheel, and will burn to a porous body without excessive shrinkage.

The clays used are commonly the less gritty sedimentary clays, for the low price of the ware seldom permits the expense of washing.

PAPER CLAYS.

These form a type of clay much used by paper manufacturers and having special qualities. Since the clays are not to be molded or burned, plasticity and behavior under fire are of no importance. The great essentials are whiteness of color and freedom from grit. The former property must be originally possessed by the clay. The percentage of grit, however, can often be lowered if the color is good.

The best grades of paper clay are imported washed kaolins, but large quantities of good paper clay are also obtained from the Potomac formation of South Carolina and Georgia, the Algonkian kaolins of Maryland and Delaware, and the white residual clays of the Cambro-Silurian formations of southeastern Pennsylvania.

GEOLOGIC DISTRIBUTION OF CLAYS EAST OF THE MISSISSIPPI.

CLAYS DERIVED FROM CRYSTALLINE ROCKS.

KAOLINS.

These include the highest grades of clay found in this country, being those which are used in the manufacture of porcelain, white earthenware, and other objects requiring a white-burning material. They are usually formed from the weathering of pegmatite veins, granites, or feldspathic gneisses, which are free from ferruginous minerals and consequently are to be sought for chiefly in those regions of metamorphic or igneous rocks in which the products of rock decay still remain. In rarer instances talcose schists seem to have been the parent rock, as in the case of those white

[a] Missouri Geol. Survey, Vol. XI, p. 486.
[b] Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. V (continued), p. 1131.

residual clays found in the great valley region of southeastern Pennsylvania. This would mean their possible occurrence in those areas of New England and the Appalachian region where igneous and metamorphic rocks of the types above mentioned are to be found, and also in similar areas in Wisconsin and Michigan. They will rarely be found in those portions of these areas lying north of the terminal moraine of the continental ice sheet, as the latter in its advance across the country scraped up most of the residual clay that had formed up to that time. Since gneissic or granitic rocks are rarely free from iron-bearing minerals, such as biotite, hornblende, garnet, etc., over large areas, the feldspar veins must be looked to for most of our supply of kaolin.

Up to the present time true kaolins are known to occur in Alabama, Delaware, Connecticut, Maryland, Massachusetts, North Carolina, Pennsylvania, and Virginia. (See Pl. IX.)

Alabama.—Kaolins occur in the eastern part of the State, in the counties of Randolph and Cleburne (see detailed account of Alabama clays, p. 68). They are rather siliceous, yet are of excellent quality, but most of them lie too far from the railroad for present utilization, and are therefore still undeveloped.

In Alabama Cambrian kaolins also are said to occur, especially in Etowah, Talladega, Calhoun, and Blount counties.

Curiously enough, these masses of white clay may often be found in close association with or even surrounded by a very ferruginous clay that carries limonite. Many of the present white-clay pits are in abandoned limonite mines.

Connecticut.—Deposits of kaolin are not usually looked for north of the terminal moraine, for the reasons already given. One deposit is known to exist near West Cornwall, and a second one is found north of New Canaan, but the latter probably lies within the State of Massachusetts. Both of these have been derived from the decay of metamorphic rocks free from iron, but the former only has been found to burn white enough for making white earthenware.

Delaware.—Kaolin pits have been worked for a number of years at Hockessin and Newark. They are formed from pegmatite veins. (See Pl. II, *A* and *B*.)

Georgia.—No mention is made in any publications of the occurrence of true kaolin in the crystalline area of this State, although the writer has seen specimens from Georgia that were undoubtedly white clay of residual character. It is very likely that veins of this material will be found by prospecting in the proper regions. The Knox dolomite yields white residual clay, but does not burn pure white.

Indiana.—Indianaite is a white clay, found in pockets of Carboniferous limestone in Lawrence, Martin, and Owen counties, Ind.

Maryland.—The feldspathic gneisses underlying the Coastal Plain formations in Cecil County seem to have been extensively decomposed, and at Northeast the kaolin

A. BALL-CLAY PIT AT EDGAR, FLA.

B. KAOLIN MINE NEAR DILLSBORO, N. C.

A. KAOLIN PIT NEAR HOCKESSIN, DEL.

Showing drift over kaolin and the starting of a circular shaft.

B. KAOLIN-WASHING PLANT OF J. T. BURGESS, HOCKESSIN, DEL.

is mined and washed for the market. The deposits have also been prospected in the surrounding area. The Maryland kaolins have been used chiefly in the manufacture of paper.

Massachusetts.—A deposit is found near Blandford. It was formed from pegmatite veins occurring in the schist of that region. It is used in the manufacture of white brick, but has not been made into higher grades of ware.

North Carolina.—This State contains some of the most important deposits of kaolin worked in the United States. They are mostly confined to the western counties of the State and were formed from pegmatite veins. (See Pl. I, *B*.)

Pennsylvania.[a]—The deposits near Brandywine Summit contain some of the oldest mines in the country. Others occur at Kaolin and Columbia. The origin of these viens is similar to those of Delaware—indeed they form part of the same group. In some cases the lower limit of the kaolin has been reached and the mine is now worked for feldspar instead of clay.

In southeastern Pennsylvania the decay of schistose or limestone rocks along the contact of the Cambrian and Silurian has yielded some white residual clays which, after washing, are suitable for white earthenware manufacture (see Pennsylvania). In the Southern States the decay of the Knox dolomite also yields them in some places (see Georgia and Tennessee), and though siliceous they are used for making fire bricks.

Virginia.—Kaolin is found in Henry and Patrick counties, and possibly elsewhere, but the deposits are just being developed. The writer has seen some very white samples of kaolin which were said to come from a locality about 50 miles west of Richmond.

General.—All of the kaolins mentioned, with the exception of those from Massachusetts, New Canaan (Conn.), Maryland, and Alabama, are being used in the manufacture of white ware. The white-burning sedimentary ball clays found in Florida are sometimes incorrectly spoken of as kaolin. The term is also incorrectly applied to certain micaceous feldspathic sands found in the Cretaceous formations of New Jersey.

The output of the American mines furnishing kaolins of proper quality is insufficient to supply the demand, and hence a large amount is imported annually from the Cornwall district of England.

IMPURE RESIDUAL CLAYS.

Many impure residual clays are found along the Appalachian belt, which have been derived from pre-Cambrian rocks. They are usually ferruginous, often gritty,

[a] Hopkins, T C., Clays of the Great Valley and South Mountain areas: Ann Rept. Pennsylvania State College, 1899–1900; Clays of southeastern Pennsylvania (in part): Idem, 1898–99.

and sometimes highly plastic. They are rarely used for anything better than common brick, but in Maryland are dug, near Dorsey, for fire brick, and at Catonsville for earthenware manufacture.

CAMBRIAN.

The Cambrian formations carry few shales which can be ground up to a plastic mass, but the residual deposits are of much commercial value.

Impure residuals.[a]—Throughout that part of the eastern United States lying south of the terminal moraine where limestones, shales, or schists are exposed, there is an abundance of residual clays, usually of high plasticity and good tensile strength, and that commonly burn red. In the upland regions of Tennessee, Kentucky, and neighboring States these Cambrian residuals are used for brick and tile, and sometimes for pottery.

In Wisconsin (see p. 262) the Cambrian shales supply residual clays, often of good quality.

LOWER SILURIAN, OR ORDOVICIAN.

The clays derived from the Ordovician or Lower Silurian formations are mostly residual, the shales being only occasionally used.

Hudson shales.—Though a widespread formation, these shales vary greatly in character from one locality to another. They form a great area in New York, but are sometimes more or less metamorphosed, and hence develop little or no plasticity on grinding. In other parts of the same State they are too siliceous, and hence have no commercial value. They are worked near Belvidere, and also near Washington, N. J., but south and west of Pennsylvania, although the shales are of common occurrence where the Ordovician is found, they are in most instances too calcareous to be used in their unweathered condition for the manufacture of clay products. The Cincinnati shales of northern Illinois have been used for pottery.

Residual clays.—These are abundantly developed in the Southern States, being derived from both the Hudson shales and the Ordovician limestones. The Trenton limestone yields the clay soils of the Blue Grass region of Kentucky, and is also found in neighboring States. These residual clays are mostly ferruginous, but are often well adapted to making brick and tile, and in some cases even pottery. Although these clays are derived from calcareous formations, the weathering leaches out most of the lime carbonate.

UPPER SILURIAN.

This system contains more shaly members than the preceding, but fewer than the Devonian, which succeeds it. The shaly members are found in the Medina, Clinton, Niagara, and Salina.

[a] See Bull. U. S. Geol. Survey No. 52. Also descriptions of clays in Alabama, Georgia, Maryland, Kentucky, and Tennessee, on later pages.

Medina shale.—This shale is found in considerable quantity in Ohio, New York, and in the middle and southern Appalachian region. It is but little used for the manufacture of clay products, partly because it is often too siliceous, ferruginous, or calcareous, and also because better clay materials are usually obtainable in the areas where it occurs. Its weathered outcrop is employed in Canada for the manufacture of dry-pressed brick. The Medina shales have been worked in Ohio for tile manufacture, but no mention is made of their having been utilized in other localities.

Clinton shale.—This may have value for the clay worker, but no mention is made anywhere of its being used. In Pennsylvania there are considerable belts of it in the east-central part of the State.[a] Outcrops also occur in western Maryland which give promising results in laboratory tests[b] (see Maryland, p. 135).

Shale of Niagara group.—This is usually highly calcareous or magnesian, and is not used in its fresh condition. It is common in New York, Pennsylvania, and Ohio.

Shale of Salina group.—This shale is especially well developed in New York State. It is soft, plastic, and molds readily when used for brick manufacture. Calcareous bands and gypsum streaks are not uncommon in it[c] (see New York, p. 172.)

DEVONIAN.

In the upper part of this system are found several important shale-bearing formations—the Chemung, Portage, and Hamilton. Under the Hamilton is the Marcellus, but this is not utilized, and indeed gives little promise.

The Hamilton is of great thickness in New York and Pennsylvania, but much less important in Ohio. In New York it is worked in the western part of the State, in Erie County, but in the eastern portion it is too siliceous to be used without mixing in the surface clay. It will probably be found suitable at many localities in Pennsylvania where argillaceous beds occur. The Portage and Chemung both carry many shale beds in southern New York, and are there much used by clay workers.[d] They are likely to be found useful in Pennsylvania. In Ohio the Hamilton beds are followed by two formations, known as the Ohio shale and the Bedford shale. The former, which is either a black or greenish shale, is siliceous, but has been used at Columbus for sewer pipe and common brick. The Bedford shale resembles the preceding somewhat, and has been used for pressed brick at Akron and also near Independence.

In the Southern States the Devonian gives good results at Cumberland, Allegany County, Md., where the formation known as the Jennings shale is employed for the manufacture of vitrified brick. The same formation when followed westward into the adjoining county of Garrett, however, shows little material of plastic character.

[a] See geological map of Pennsylvania, Final Summary Report Pennsylvania Geol. Survey, 1893.
[b] Maryland Geol. Survey, Vol. IV, p. 455.
[c] Bull. New York State Museum No. 35, p. 829.
[d] Ibid., pp. 834 and 836.

The Devonian shales are known in Tennessee, Kentucky, Georgia, and Alabama, but their extent is not comparable with that seen in the North.

In Michigan the Marshall shale series of the Devonian is well developed around Jordan, and its weathered outcrop yields some tough plastic clays.[a] The Hamilton shales outcrop around Alpena.

In Indiana the Devonian underlies a great area in the central part of the State, but offers little promise to the clay worker.

CARBONIFEROUS.

This system contains the most widely distributed and perhaps the most important clay-bearing formations found in the eastern United States, being important in Pennsylvania, Ohio, West Virginia, Kentucky, Indiana, Illinois, and Michigan, and of less importance in Maryland, Virginia, Alabama, and Tennessee.

In the Appalachian area, especially of Pennsylvania, Ohio, West Virginia, Maryland, and Virginia, the Carboniferous section remains fairly uniform, and contains the following members, enumerated in order, from above downward:

Carboniferous formations in Appalachian region.

1. Upper Barren Measures, or Dunkard group.
2. Upper Productive Measures, or Monongahela group.
3. Lower Barren Measures, or Conemaugh group.
4. Lower Productive Measures, or Allegheny group.
5. Pottsville conglomerate, or New River group.

The Upper and Lower Productive Measures contain each several coal beds of well-marked stratigraphic position, which are often underlain by persistent beds of fire clay. The Pottsville conglomerate may also carry fire-clay deposits, while the Upper and Lower Barren Measures contain inexhaustible supplies of shale suitable for common, pressed, and vitrified brick and roofing tile.

Pottsville conglomerate.—This is made up largely of hard sandstones and conglomerates, but carries several beds of fire clay associated with the Mercer coals. The well-known Mount Savage clay, mined in Allegany County, Md., and also in Somerset County, Pa., is from this horizon. In Mercer County, Pa., fire clay underlies the Sharon coal, and in the Hanging Rock district of Scioto County, Ohio, fire clays are found under the Upper and Lower Mercer and Quakertown coals. The clay underlying the latter has furnished an important supply of pottery material. On the whole, however, the conglomerate series is not nearly so important to the clay worker as the higher-lying ones.

Lower Coal Measures.—These contain a number of valuable deposits of fire clay. The thickness of the series is 300 feet in western Pennsylvania, and rarely less than

[a] Ries, H., The clays and shales of Michigan: Michigan Geol. Survey, Vol. VIII, Pt. I, p 45.

250 feet in any other part of the State. In Ohio it is less than 200 feet, but it thickens southward, so that in the region of the Kanawha River it is 1,000 feet thick.[a] Beginning at the top, the following members are recognized:

Section of Lower Coal Measures.

1. Upper Freeport coal.
2. Upper Freeport limestone.
3. Lower Freeport coal.
4. Lower Freeport limestone.
5. Freeport sandstone.
6. Johnstown coal.
7. Johnstown cement.
8. Kittanning middle coal.
9. Kittanning lower coal.
10. Kittanning sandstone.
11. Buhrstone iron ore.
12. Ferriferous limestone.
13. Clarion coal.
14. Brookville coal.

Of this section fire clays are found under 1, 3, 6, 8, 9, 12, 13, and 14.

Wherever the Upper Freeport limestone is absent or thin, a fire clay known as the Bolivar clay comes in. It is a fine nonplastic or flint clay, found especially in Westmoreland, Fayette, and other counties of Pennsylvania. In Ohio it is said to be valuable at only one or two points, in Jefferson and Muskingum counties, while in West Virginia it is valuable only on Deckers Creek, in Preston and Monongalia counties.[b] It has recently been found in Garrett County, Md.[c]

Another important bed of fire clay is found in many regions under the Lower Kittanning coal. In parts of West Virginia and at several places in Ohio it does not all immediately underlie the coal, but may reach down nearly to the top of the Ferriferous limestone.[d] East of the Allegheny River it does not appear to be very important, but west of that river it is generally present and attains its maximum development along the Beaver and west of that stream, down the Ohio, the potteries of New Brighton, Rochester, East Liverpool, New Cumberland, and other points in these valleys all deriving their clay from this horizon. Prof. I. C. White makes the following statement concerning this bed:[e]

"In the Beaver County region the thickness is generally about 8 to 10 feet, but occasionally runs up to 15 and down to 5. It often consists of two portions—an upper soft clay and a lower hard clay, the latter being used in the manufacture of fire brick, etc. In western Pennsylvania and eastern Ohio this clay bed is often a very valuable element in settling questions of stratigraphy which would otherwise be extremely difficult of solution; in fact, it is valuable for this purpose clear across

[a] White, I. C., Bull. U. S. Geol. Survey No. 65, p. 99.
[b] Ibid., p. 159–160.
[c] Maryland Geol. Survey, Vol. IV, p. 503.
[d] White, I. C., Bull. U. S. Geol. Survey No. 65, p. 172.
[e] Ibid.

the Ohio coal field, since, according to Orton, although not entirely persistent, yet it furnishes valuable clay mines in every county of its outcrop from the Pennsylvania line across the Kentucky border.

"In West Virginia (except along the Upper Ohio River) the deposit is seldom of value, being too silicious, and it has been developed in only one region, viz, at Nuzums [now Hammond] on the Tygarts Valley River. Here, along the crown of the Chesnut Ridge anticlinal, the coal above disappears locally, and then a valuable bed of hard clay replaces it, just as it often does in Ohio, when the hard flinty clay is present."

A bed of good fire clay often underlies the Clarion coal in both Ohio and Pennsylvania, and may at times rest directly on the Pottsville conglomerate.[a] A good fire clay is also seen under the Brookville coal in some parts of Pennsylvania, especially Jefferson and Clarion counties. It is mined in Clearfield County, at Blue Ball, Wallaceton, and other points along the line of the Tyrone and Clearfield road.[b] A fire clay is found under the Middle Kittanning coal in Pennsylvania in the counties of Armstrong, Beaver, Allegheny, Blair, and Tioga, and another bed is known under the Upper Kittanning.

In Ohio the Lower Freeport clay has not been developed, although Prof. E. Orton, jr., states that there is a good flint clay at this horizon southeast of Zanesville.

Lower Barren Measures or Conemaugh group.—The upper part consists chiefly of shales, while the lower portion shows more massive sandstones. Among the former there are many red and marly shales, which make a broad band of red soil extending from Pennsylvania southward through central West Virginia and beyond the Kentucky line. Their outcrops then circle around through eastern Kentucky and southern Ohio and back to Pennsylvania. The group shows a maximum thickness of 800 feet near Charleston, W. Va., and a minimum of 300 feet along its northwest border in Ohio. It averages about 600 feet in Pennsylvania and northern West Virginia. The many beds of shale, though lacking in fire clays, should form an inexhaustible supply of material for making common, pressed, and paving brick, roofing tile, floor tile, terra cotta, etc. They are utilized in Allegheny County, Pa., and at Clarksburg, Fairmont, Charleston, and Huntington, W. Va. They are not wanting in Ohio, but have not thus far been used.

Upper Coal Measures or Monongahela group.—This series begins at the base of the Pittsburg coal and extends to the Cassville shales. Its greatest development is along the Monongahela River in southwestern Pennsylvania and West Virginia. It contains six distinct coal seams. At the northern end of the basin interstratified rocks are mostly limestones,[c] but toward the south these disappear and red shales take their place. This change shows itself in the more subdued character of the topography.

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[a] White, I. C., Bull. U. S. Geol. Survey No. 65, p. 176. [b] Ibid., p. 178. [c] Ibid., p. 43.

Up to the present time the rocks of this series have been little used outside of western Pennsylvania, but they offer, no doubt, an important field for exploitation by the clay worker.

Upper Barren Measures, Permo-Carboniferous or Dunkard group.—Concerning these, I. C. White makes the following statement:[a]

"These deposits occupy a rather limited area in the Appalachian field, being found in only two counties (Greene and Washington) of Pennsylvania, with the exception of small isolated patches in Fayette, Westmoreland, and Allegheny. In Ohio there is a larger area of them bordering the Ohio River through the counties of Belmont, Monroe, Washington, Meigs, and Gallia. But it is in West Virginia that we find the principal belt of these beds, for there they cover a wide region bordering the Ohio River between the Pennsylvania line at the north and the Great Kanawha River on the south.

"The character of the rocks varies greatly in different portions of this area. At the northeastern end of the field, in Washington County, Pa., limestones seem to predominate in thickness over the gray shales, sandstones, and thin coal beds with which they are there interstratified. But southwestward the limestones and coals gradually disappear, so that in Jackson County, W. Va., no regular coal beds are found, and only one limestone (the Nineveh) remains. The limestones continue in considerable number in Greene, Ohio, Marshall, and Monongalia counties and the southern part of Wetzel County, but southward from this line they rapidly disappear, with the single exception noted. The coal beds all die out with the disappearance of the limestone except one (the Washington), which seems to extend beyond the Little Kanawha River before it passes out of the series.

"As the limestones and thin coal beds gradually fade out to the southwest, red shale, a variety of rock almost unknown in Washington County, Pa., gradually comes into the section, in thin beds at first, but finally extends throughout the whole series and forms nearly one-half its thickness, thus making a broad band of red soil from the Pennsylvania line southwestward to the Great Kanawha River."

The series contains little fire clay and the shales have not been used except, perhaps, in Pennsylvania.

The Carboniferous section of the other States included in the area under discussion is not wanting in clays and shales. Alabama contains many Carboniferous shale deposits of commercial value, some of which are now utilized in the manufacture of paving brick. The Carboniferous coals of both Tennessee and Kentucky are often underlain by deposits of fire clay, a few of which have been worked, but there is still great opportunity for much profitable exploitation. Some of the more important clay seams of Ohio are traceable across the border into Kentucky. In Indiana many beds of fire clay, stoneware clay, and shale are found interbedded with the coal beds of the Coal Measures in the southwestern part of the State, and they have been sufficiently developed to demonstrate their value for many different purposes. Illi-

[a] White, I. C., Bull. U. S. Geol. Survey No. 65, p. 43.

nois also contains many beds of clay, especially under the lower coal seams found in the Carboniferous section of that State. In addition to these there are also heavy beds of shale which have been extensively used in the manufacture of paving brick and other clay products.

Owing to the absence of folding in the Coal Measures of both Indiana and Illinois and to the fact that the country is flatter than that in the Appalachian States, the seams often have no outcrop, and consequently shaft mining has to be resorted to.

Many beds of shale are found in the Coal Measures and the Lower Carboniferous formations of Michigan, but up to the present time they have been but little developed. The work that has been done shows that the shales are adapted to the manufacture of paving brick, pressed brick, and sewer pipe, but that fire clays are not likely to be found, for although many shafts have already been sunk in mining the coal of that State, not one bed of refractory clay has been encountered.

Considering the Carboniferous system as a whole, it is seen that it is a most valuable one to the clay worker, as it contains all grades of clay in inexhaustible quantities. These deposits are referred to in much greater detail under the various States.

JURATRIAS, OR NEWARK.

This formation is composed chiefly of red micaceous sandstones, and has up to the present time been of little value to the clay worker. It is found in the Connecticut Valley in Connecticut and Massachusetts, and in southeastern New York, and it extends in a belt across New Jersey and Pennsylvania and into Maryland. A narrow area of it is found in North Carolina and Virginia. Throughout this region it is composed chiefly of micaceous sandstones, but in places may also carry shale beds. Up to the present time these shale members have not been used by the clay worker, except in one locality in North Carolina. As a rule they are too micaceous or sandy, and develop little plasticity on being ground and mixed with water. Furthermore, on account of their high percentage of iron oxide, they fuse or sinter at a very low temperature. In North Carolina the weathered outcrops of the Triassic shales have been used as an ingredient in sewer-pipe mixtures. It is also possible that the shales associated with the Triassic coals in the Richmond field of Virginia and in the neighboring area of North Carolina may be found suitable for the uses of the clay worker, but up to the present time they remain untouched.

CRETACEOUS.

The Cretaceous system is an important source of plastic materials throughout the Coastal Plain region of the Atlantic and the Gulf States, since it carries clay deposits throughout its entire length from Marthas Vineyard to Mississippi. As it embraces the oldest of the formations underlying the Coastal Plain and as these dip

southeastward, it is found outcropping along the western and northwestern edge of this area. The outcrop forms a belt of variable width, which reaches its maximum in the Southern States. The clays found in the Cretaceous formations represent nearly every class of plastic material known, ranging from those that are very impure or very sandy to others showing a high degree of purity or extreme fineness of grain. Consequently they furnish a supply of material that is suitable for the manufacture of many different kinds of ware. The general section of the formation varies somewhat from place to place and is referred to in the detailed descriptions under the different States.

The Cretaceous system is divisible into a lower group of sands, gravels, and clays and an upper or marine group of sandstones and marls.[a]

The nonmarine or lower division is the most important to the clay worker. It extends across New Jersey from Perth Amboy to Philadelphia, then across Maryland and beyond, passing by way of Alexandria, Fredericksburg, and Richmond to the vicinity of Petersburg. It is well exposed at many points along the Rappahannock and James rivers, but only to a small extent along the Appomattox. South of Petersburg the exposures are few, most of the Cretaceous formation being covered by Tertiary deposits, so that the former appears only in river cuttings.

In the Gulf-border region the inland boundary of the Cretaceous extends from a point on the Mississippi River a few miles above its confluence with the Ohio to a point on the Savannah River near Augusta, Ga. From the point of beginning just mentioned it extends eastward to a point on the Ohio River a few miles above its confluence with the Tennessee River, and from there it may be followed along a strongly convex and not very irregular line to the eastern terminus. From its northerly point within western Kentucky the direction of this line is almost due south, through western Tennessee and northeastern Mississippi. There it takes a southeasterly direction and passes into northwestern Alabama. Thence by a broad curve it passes nearly centrally through Alabama, and through a part of Georgia, to the point near Augusta mentioned above.

The structural characters of the Cretaceous are very similar throughout the area under consideration, the deposits being made up of a series of alternating beds of sand, clay, and gravel. In some places the beds of clay are fairly persistent, as in New Jersey, but in most of the States where the Cretaceous is exposed the clay beds are usually of a lenticular character, interbedded with and surrounded by masses of sand. (Fig. 3.) This structural peculiarity is due to the ever-changing conditions under which the beds were deposited, the water over the same area being at one time quiet, when fine clay would be deposited, and at other times rough, owing to the shifting of the currents, when more sandy material would be laid down. This

[a] See Bull. U. S. Geol. Survey No. 82, Correlation papers—Cretaceous.

fact indicates the necessity of carefully exploiting any deposit in this region before a factory is located near it. In the northeastern part of the area the Cretaceous clays occur on Marthas Vineyard, and are well exposed in the section at Gay Head. At this locality there are some small deposits of refractory material, but the clays are often covered by a large amount of overburden and have been much disturbed by ice action, resulting in the mixing up of pure and impure layers, thus rendering the working of them rather difficult. Farther southwest the Cretaceous beds outcrop at a few points on the northern shore of Long Island, where they are worked for obtaining a refractory or semirefractory siliceous clay, used chiefly in the manufacture of stoneware. Deposits of limited extent and similar nature are also known on Staten Island. The most important development of the Cretaceous clays occurs

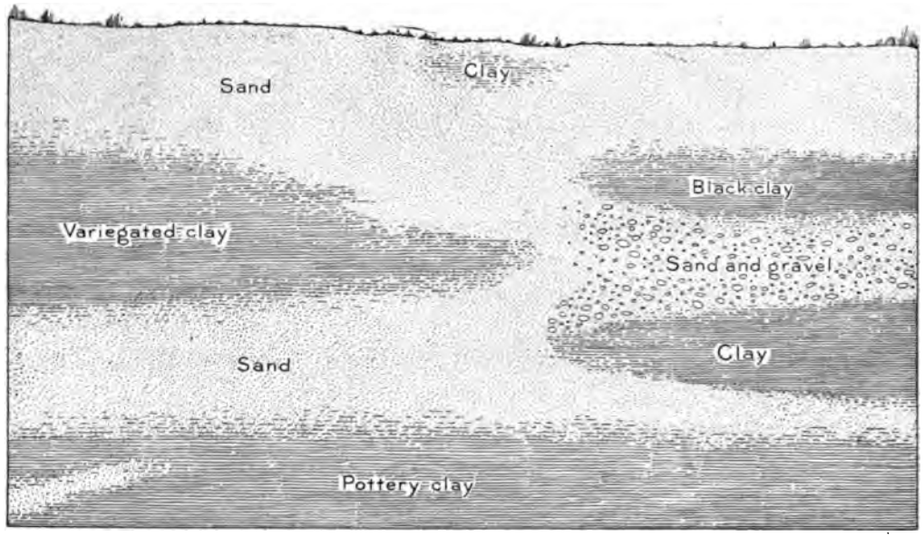

FIG. 3.—Section showing lenticular character of clay deposits in Coastal Plain region.

in New Jersey, where Lower Cretaceous beds form a strip 4 to 6 miles wide, extending in a northeast-southwest direction from the vicinity of South Amboy to a point opposite Philadelphia. In this section several well-marked members have been found, such as the Woodbridge fire-clay bed, the Amboy fire clay, and the Amboy stoneware clay. These have been worked for a number of years, as will be seen from the detailed description of them given under New Jersey. They supply a great variety of clays, ranging from the most refractory to the most fusible. In the seventies it was only the more refractory grades that were chiefly sought after, but since that time uses have been found for the poorer qualities of clay found in the New Jersey area. These are being much exploited at the present time, and are used

especially for the manufacture of hollow brick and conduits. The Upper Cretaceous beds which outcrop to the southeast contain two important beds of clay marl, which are of much value for the manufacture of brick, tile, earthenware, and possibly other low- or medium-grade wares. They are well exposed near Matawan, Moorestown, and Camden.

In Maryland the Cretaceous beds extend across the State in a belt about 12 miles wide, through Cecil, Harford, Baltimore, Howard, Anne Arundel, and Prince George counties. Here these clay beds belong to the Potomac group of the Lower Cretaceous, which is also important. In Anne Arundel County its width of outcrop is great. As pointed out under Maryland (p. 139), the lower or Patuxent member is usually sandy, but may carry refractory clays.

The Arundel formation, which is especially developed in Anne Arundel County, carries large deposits of brick clays. The Patapsco yields the greatest variety of clays found in the Cretaceous within the boundaries of Maryland, embracing stoneware clays, fire clays, and brick clays. The Raritan, which overlies it, is little worked, although clay beds are well developed in it along the Magothy and Severn rivers.

The clays of the District of Columbia are similar to those of Maryland, but their continuation across Virginia is narrow and their commercial value is not in all cases well known.

In Georgia the Cretaceous outcrops form a triangular area having its apex at Macon and following the fall line to the Chattahoochee River. The sections show many deposits of white clay of highly refractory character but of low plasticity and tensile strength.

In North Carolina the Cretaceous beds outcrop near the western border of the Coastal Plain, but carry little clay of value.

In South Carolina the Potomac group of the Cretaceous forms a belt 4 or 5 miles wide, extending through Aiken, south of Lexington, and through Columbia to Camden and Cheraw.[a] The finer clays occur near the top of the formation, or toward its southeastern edge.

The Cretaceous becomes of great importance in Alabama, especially in the Lower Cretaceous or Tuscaloosa formation, which carries clays of varied character, some being nearly pure or white, others dark gray and very plastic, and some ferruginous. So far as the writer's observations have gone the Cretaceous clays of Alabama rank next to those of New Jersey in general quality. The formation crosses Alabama in a general northwesterly direction, forming a curve that enters the State at Columbus, Ga., and leaves it in Colbert County, at the Mississippi border. It forms the northeast corner of Mississippi and small areas in Tennessee and Kentucky.

[a] Bull. U. S. Geol. Survey No. 138, p. 208.

TERTIARY.

The formations of this age have thus far proved to be of little value to the clay worker, although they are widely distributed throughout the Coastal Plain region and up the Mississippi Valley as far as Ohio, overlying the Cretaceous and, indeed, sometimes completely hiding it. They, in turn, may be covered by Pleistocene deposits.

Owing to the complexity of their relations to other formations it is often difficult to recognize the Tertiary beds, and detailed statements regarding them are given under the descriptions of the States rather than here. The formations consist of a series of sands, marls, and some clays. The latter are usually of local extent.

In New Jersey (see p. 166) the Miocene clays are worked for brick. In Maryland (see p. 143) a red clay of importance is found in the Eocene. Tertiary clays are worked in North Carolina and Georgia and are of importance. Many deposits are also said to exist in Alabama and are now being studied by the geological survey of that State.

The Tertiary clays of western Kentucky and Tennessee are perhaps as important as any in the eastern United States, and are actively worked at several points for fire brick and stoneware. In the former State they are restricted to the Jackson Purchase region.

The Lafayette formation, of Upper Tertiary age, is a prominent member of the Coastal Plain deposits, and consists of a series of loams, clays, sands, and gravels, usually of orange color. It extends from New Jersey southward to Florida and thence westward, its greatest width being on the Roanoke River.[a] In central Georgia it stretches from the fall line to the inland margin of the coastal sands all the way from the Savannah to the Chattahoochee River. It expands greatly in Alabama, forming an almost continuous belt reaching from the fall line at Montgomery and Tuscaloosa to Mobile Bay, and it is even more extensive in Mississippi.

The Lafayette formation may contain a variety of clay deposits,[b] especially in western Kentucky and Tennessee, but there is doubt whether these clays are really of Lafayette age.

In most regions the Lafayette forms an objectionable mantle of sands and gravels over the Cretaceous and early Tertiary clay-bearing beds under it.

PLEISTOCENE.

The Pleistocene formations serve as the chief source of brick- and tile-making materials in the United States east of the Mississippi, the deposits, which are often clays or loams, forming a great mantle over the pre-Pleistocene beds.

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[a] Twelfth Ann. Rept. U. S. Geol. Survey, Pt. I, p. 489.

[b] Ibid., p. 505.

In the area north of the terminal moraine the clays are found in ponded valleys in the glacial till, underlying terraces along rivers, or around the Great Lakes. They are well adapted to the manufacture of the lower grades of clay products, such as common brick and earthenware, and less often paving brick, terra cotta, sewer pipe, and stoneware.

In the more Southern States the Pleistocene clays form plastic loams in the lower-lying districts, especially along the main river valleys and estuaries of the coastal region, and are known as the Columbia formation, the type locality of which is in the District of Columbia, where it is well developed along the Potomac River. There it consists of a sheet of brown loam, passing down into a bed of pebbles and bowlders.[a] The loam ranges from 3 or 4 to 20 or 30 feet in thickness.

To the north the formation grades into pebbly beds in southern New Jersey, while the sandy clays are well developed along some of the waterways, such as the Rappahannock, the James, the Appomattox, the Roanoke, and intermediate rivers, but farther south they increase greatly in sandiness.

In some of the Southern States, as Alabama,[b] there are extensive stretches of fluvial or river deposits of Columbia loam, known as "second bottoms," which stretch from the coastal zone to the fall line and sometimes beyond. Typical exposures of second-bottom loam occur along the Chattahoochee River about Columbus, Ga., and on the Tuscaloosa River at Tuscaloosa, Ala. They are worked around Philadelphia, Baltimore, Washington, and other cities. The clays underlying the flood plains of the broader river valleys in the South may also be placed here.

DISTRIBUTION OF CLAYS BY KINDS.

BRICK CLAYS.

There is no grade of clay which is more widely distributed or found in larger quantities than common brick clay, hardly a township being without an available deposit. (For distribution see Pls. III, IV, and VII.)

In the northeastern or New England States practically all the brick clays are glacial deposits, in some places filling depressions, in others included in the drift, or elsewhere underlying terraces along river valleys.

In New York many kinds of brick clays are obtained from the drift deposits,[c] but the Silurian shales of central New York, the Devonian shales of southern New York, and the Cretaceous clays of Long Island may likewise be drawn upon.

In Pennsylvania the drift clays and river-terrace clays are still available and are used both in western Pennsylvania and around Philadelphia. In addition to these, however, there are the mellowed outcrops of the Carboniferous and Devonian shales,

[a] Twelfth Ann. Rept. U. S. Geol. Surv., Pt. I, p. 384. [b] Ibid., p. 389. [c] See New York Pleistocene clays, p. 175.

the former especially being extensively used around Pittsburg, the latter as yet at only a few isolated localities. In addition to these the residual clays of the Great Valley region are much employed.

Throughout the Southern States brick clays are dug from the Columbia loams and Cretaceous beds of the Coastal Plain region, and from residual deposits in the uplands. The wash from the latter may often be collected in the valley bottoms and serve to supply some local brickyard.

In Ohio, Indiana, Illinois, Michigan, and Wisconsin the drift clays are almost invariably drawn upon for common brick materials, for they lie on the surface and the clay is therefore easily obtained and worked. The same formations are often drawn upon for earthenware clays, except that it is usually the less sandy beds that are sought. If red earthenware is to be made the calcareous deposits are avoided. These are not very abundant, except in Indiana, Illinois, Wisconsin, and Michigan.

PRESSED-BRICK AND TERRA-COTTA CLAYS.

Since these two grades of ware are being made from very similar raw materials at the present day, they can be discussed together. Two classes of clay are used—refractory or buff-burning clays and red-burning ones. The refractory clay sought is commonly a No. 2 fire clay, and must be obtained mostly from either the Cretaceous or the Carboniferous formations, and hence its distribution is limited. Since pressed brick and terra cotta both command a good price, the manufacturer can afford to transport the product some distance to the market.

In Massachusetts, at Blandford and south of Clayton, there are residual clays which have been used for light-colored wares, but the clay had to be mixed with more plastic material brought from other States. New York has limited quantities of the proper clay on Staten Island and Long Island. In New Jersey much buff-burning material can be dug from the Cretaceous deposits, and the same is known to be true of Maryland and Alabama. The Tertiary deposits may also yield some light-burning clays in New Jersey.

In Ohio, Pennsylvania, and Indiana great supplies are obtainable from the clay underlying the coal. Illinois, Kentucky, and Tennessee may prove to have similar supplies, but the two last-named States are still far from the markets consuming the greatest quantities of terra cotta. The Tertiary and Pleistocene formations of the Atlantic and Gulf coast contain at times beds of buff-burning, semirefractory clays.[a] Calcareous clays might also be used for buff wares, but they are not preferred, owing to their low fusibility.

Red terra-cotta and brick clays are obtainable from the same formations as common brick clays, but there is little demand for them at the present time. Many

[a] See New Jersey, p. 166.

of the Carboniferous shales, and even Devonian ones, have been found to yield a rich red color. Such are used near Pittsburg, Pa., and Corning, N. Y.

STONEWARE CLAYS.

Under this title may be included those semirefractory clays that are used for many other kinds of material than stoneware, all of which, however, call for a dense burning clay of moderate fire-resisting quality. Their distribution is rather restricted (see Pls. III, IV, and VII). Most important are the deposits of Carboniferous age, especially those of the Lower Coal Measures, for in these rocks considerable deposits of plastic clay are often found underlying the coal seams. They are worked to an enormous extent in Ohio to supply the stoneware industry of that State, and among these clays the Lower Kittanning is especially important. The same beds are worked in the eastern extension of these rocks in western Pennsylvania, but they are not utilized in Kentucky or West Virginia, though they may occur. In New Jersey good stoneware clays are found in the Cretaceous belt, especially in Middlesex County, and in rocks of the same age in Maryland, especially in Cecil County, but in no State are they as valuable as the Ohio materials.

Beds of good quality are found underlying many of the coals in southwestern Indiana and probably Illinois, but little is known of the occurrence of any in Michigan or Wisconsin. Stoneware clays occur in the Cretaceous of Alabama, especially in the counties of Autauga, Perry, Bibb, Tuscaloosa, Pickens, Fayette, Lamar, and Franklin.[a] They may be looked for in the Cretaceous area of Jones, Baldwin, Twiggs, and Wilkinson counties, Ga., in the Jackson Purchase of western Kentucky, and especially in the Tertiary formations and beds of similar age in western Tennessee.

FIRE CLAYS.

These are widely distributed, both geologically and geographically, being found in 21 States out of the 24 lying east of the Mississippi, and in three of these, viz, Ohio, Pennsylvania, and New Jersey, they are of vast importance (see Pls. III, IV, and VII). Refractory clays are commonly used in the State in which they are mined, but in some States much of the supply is shipped. Thus fire clay from New Jersey is sent to Ohio, Pennsylvania, West Virginia, New York, Massachusetts, Connecticut, Maryland, and Maine. Indiana clay is sent in small quantities to Kentucky and Georgia, and Alabama clay is sent to Tennessee.

The uses of fire clay have been already referred to under another head.[b] Attention should once more be drawn to the fact, however, that the term "fire clay" is very loosely used, so that clays are termed "fire clays" which have no claim to the title. Bricks that are used for boiler settings are called "fire brick," but experiment shows that they melt completely at cone 27 or lower.

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[a] See Alabama, p. 71.

[b] See "Uses of clay," p. 37.

The following table shows the refractoriness of some of our better American fire clays, the figures being the result of tests made by H. O. Hofman and the writer:

Refractoriness of American fire clays as shown by tests made with Segers cones.

Locality.	Fusion point.
	Cone.
Kreischerville, N. Y., No. 1 white	35+
St. Louis, Mo., Christy raw clay	31–30
Golden, Colo	32–31
Mineral Point, Ohio	33
Mount Savage, Md	33
Sayreville, N. J	35
Woodbridge, N. J	34

Most of the fire clay mined goes into fire brick, but large quantities are used as one of the clays in mixtures for saggers, terra cotta, zinc retorts, gas retorts, stoneware, etc.

As the refractory clays are of much value their distribution is here given in some detail.

Alabama.—The residual clays or kaolins of Randolph and Cleburne counties are very refractory, although they lack plasticity. Their most important use will probably be for china manufacture rather than fire brick. Similar white clays are found at times in the residual clays of the Cambro-Silurian areas, as in Calhoun and Cherokee counties. White refractory clays are found in the Lower Carboniferous clays of the Wills Valley region and are worked for shipment to fire-brick factories at Chattanooga, Tenn. No fire-clay deposits have been discovered in the Coal Measures up to the present time.

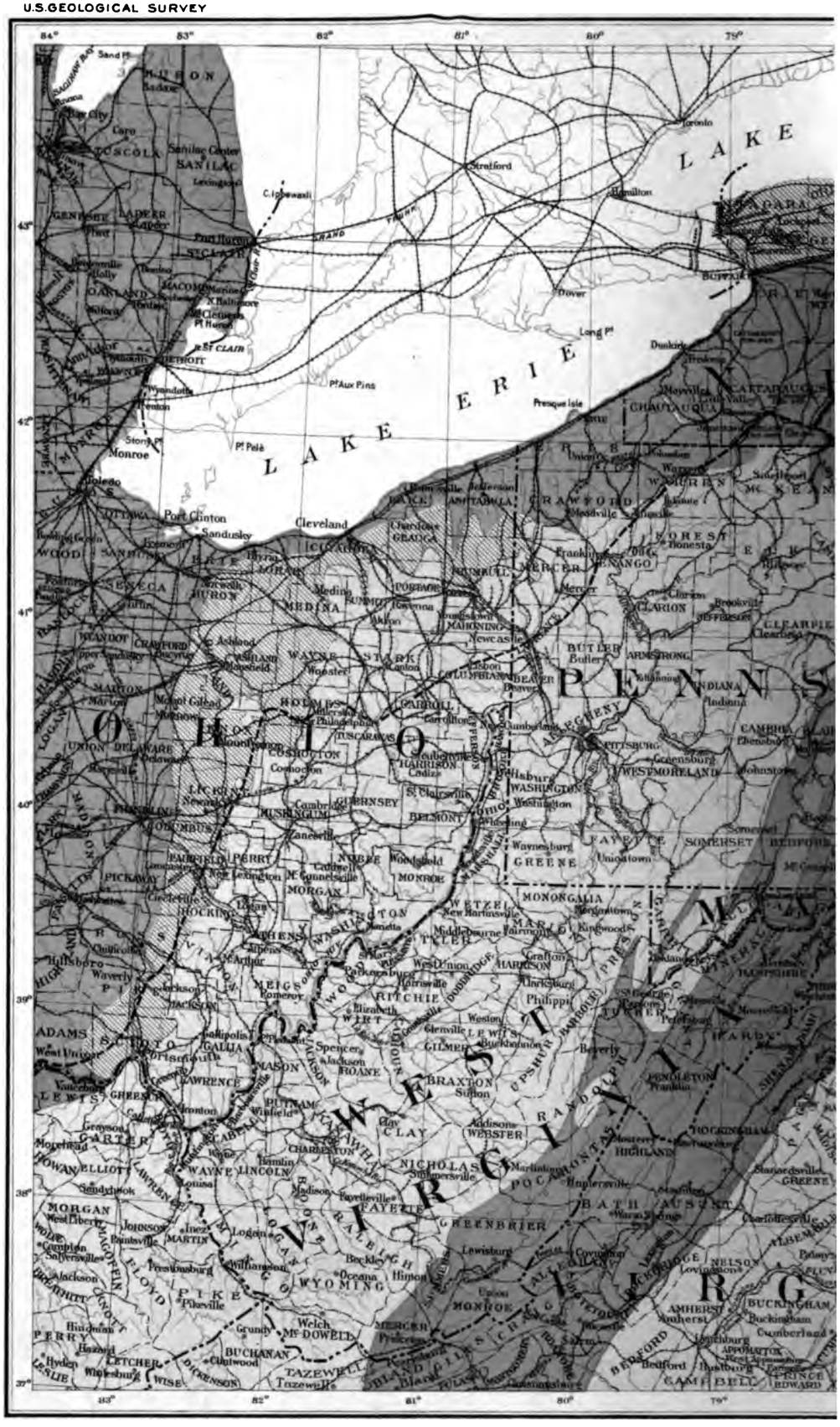
Refractory clays are most commonly found in the Tuscaloosa formation (Lower Cretaceous), being worked at Woodstock, Bibbville, and other places. They usually possess high plasticity and often burn dense at a comparatively low temperature. Other important occurrences are at Hull station and Tuscaloosa, in Tuscaloosa County; Potters Mills, Marion County; and Pegram, Colbert County.

The Tertiary may contain fire clays, but they have not thus far been exploited. A peculiar flint-like clay is found in Choctaw, Conecuh County.

Georgia.—The fire clays of this State are derived chiefly from the Cretaceous and Paleozoic formations. The best fire clays are those found in the Potomac group of the Cretaceous, in the southeastern part of the State. They form lenses of white clay, having very high refractoriness but low plasticity. Important areas are located around Griswoldville, Lewiston, Butler, and Macon.

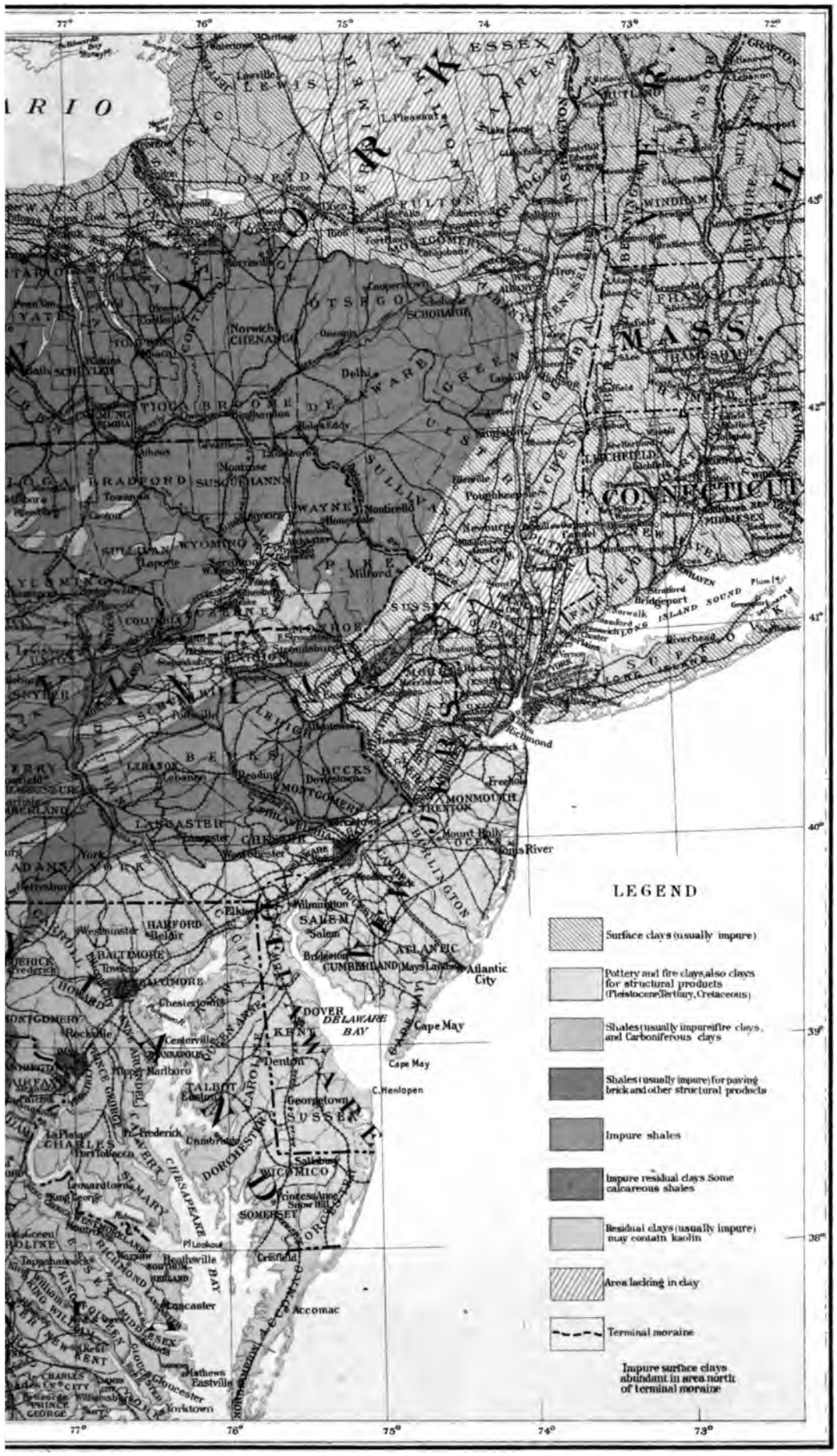
Many residual clays have come from the decomposition of the Cambrian and

U.S.GEOLOGICAL SURVEY



MAP SHOWING DISTRIBUTION OF CLA

25 0 25 50 75



ORTHERN APPALACHIAN REGION

125 150 175 200 miles

Ordovician limestones, and these, though commonly ferruginous, often contain white siliceous clays of good fire-resisting qualities.

Indiana.—The only rocks in Indiana carrying fire clays are of Carboniferous age, found in the southwest corner of the State. They usually underlie the coal seams, and several of them are persistent. They vary in thickness, but are often 3 to 4 feet thick. They are commonly mined by means of shafts, from which coal also is extracted. Actual fire tests are lacking, but the Indiana clays are probably not so refractory as those found in Pennsylvania and New Jersey or in Ohio.

Kentucky.—Analyses published by the Kentucky geological survey[a] show the presence of many fire clays in the Carboniferous. The beds of clay often underlie the coal, but their degree of persistence is not known, nor do many of them seem to have been developed. In Greenup, Boyd, Carter, and Lawrence counties one bed of fire clay is known near the base of the Subconglomerate, and another under coal No. 6. The former is a flint clay and is said to resemble that found at Sciotoville, Ohio. Fire clays are also known under seams 2, 3, 4, 5, 6, 7, 8 in the eastern field,[b] but are not always present, and in some cases may be thin enough to require mining with the coal. Fire clay is sometimes found in the Upper Ferriferous limestone in Greenup, Carter, and Boyd counties and has been used in the manufacture of fire brick. Refractory clays occur, no doubt, in the western coal field, but little has been published concerning them.

Many fire clays occur in the Tertiary and also in the Cretaceous of the Jackson Purchase region, but they have been used more for the manufacture of stoneware than for fire brick.

Maryland.—Refractory clays exist in the Algonkian, Cretaceous, and Carboniferous. The Algonkian refractories are residual in character and are found along the western border of the Coastal Plain area, especially at Dorsey and Northeast. Those of the Potomac formation are found chiefly in the Patuxent and Raritan members, but also show in the Patapsco. They do not occupy any definite stratigraphic position, and form more or less lenticular masses. Many of them are decidedly refractory and of low shrinkage, but are rather low in bonding power. Their chief use is for the manufacture of stove brick, fire brick, and gas retorts.

The Carboniferous fire clays are the basis of an important local industry in Allegany County and are found in the Conglomerate series belonging under the Mount Savage coal. Both the flint and the plastic varieties occur. They are known at several points on Savage Mountain, also at Swallows Falls and Blaine, Garrett County. More recently the Bolivar fire clay has been found on the Castleman River in Garrett County. The Carboniferous fire clays are much used for fire brick and also for enameled brick.

[a] See Kentucky Geol. Survey, Chem. Anal., Pts. I, II, III. [b] See detailed account of Kentucky clays, p. 112 this paper.

Michigan.—No fire clays have thus far been discovered in this State.

Mississippi.—Fire clays are found in the Cretaceous and Tertiary beds of the northeastern portion of the State; but they are not extensively worked.

New Jersey.—Few States contain a more important series of refractory clays than does this one, and although they are confined almost exclusively to the Lower Cretaceous beds, they have been worked for many years not only to support a local industry but also to supply factories in other States. Curiously enough, this same member of the Cretaceous carries much less refractory clay in the States farther south. In New Jersey several well-marked members are recognized in the series of Middlesex County, including the Woodbridge fire clay, Amboy bed, and Raritan bed. The materials are all plastic, soft, and range in refractoriness from low-grade fire clays up to others of high heat-resisting power.

New York.—The fire clays occur in small quantity on Staten Island and at several points on the north shore of Long Island. Few of them are highly refractory. They are usually sandy and plastic.

North Carolina.—The only highly refractory clays that have been found in this State are the kaolins resulting from the decay of pegmatite veins. They are of more value for making white ware than for the manufacture of fire bricks.

Ohio.—This State is one of the two most important producers of refractory clay products. The fire clays are obtained entirely from the Carboniferous, especially the Coal Measures. In the Lower Carboniferous an important flint clay is worked at Sciotoville and Portsmouth. In the Conglomerate measures the Tionesta, Upper and Lower Mercer, Sharon, and Quakertown coals are underlain by a seam of fire clay, which is worked at Massillon, the Lower Mercer being worked in Stark, Tuscarawas, Hocking, and Muskingum counties. In the Lower Coal Measures, clay underlies the Upper and Lower Freeport, Middle and Lower Kittanning, and Brookville coals. That from the Kittanning far exceeds all the others in value and is extensively worked.

Pennsylvania.—Refractory clays are found in the Cambro-Silurian and Carboniferous formations. The former occur mainly in southeastern Pennsylvania, and result from the decomposition of talcose schists, slates, and limestones. The latter are found in western and central Pennsylvania and serve as the basis of a large industry. They are referred to in some detail under Pennsylvania, but their distribution may be summarized as follows:

Distribution of Carboniferous formations in Pennsylvania.

CONGLOMERATE GROUP.

Alton fire clay; Elk County.
Mercer clay; North Butte, Beaver, Lawrence, and Mercer counties.
Sharon clay; Elk and Mercer counties.

Distribution of Carboniferous formations in Pennsylvania—Continued.

LOWER PRODUCTIVE MEASURES.

Brookville clay; Clearfield, Elk, and Jefferson counties.

Clarion clay; Indiana and Beaver counties.

Ferriferous; Armstrong County; hard and also semiplastic.

Kittanning fire clay; a valuable refractory plastic clay, sometimes termed the New Brighton. Known in several counties, including Armstrong, Beaver, Tioga, Blair, Fayette, and Westmoreland.

Upper Freeport or Bolivar; the important flint clay deposit of Pennsylvania. Widely distributed, but not always refractory, for its place may be taken by shale. It has been noted in Allegheny, Armstrong, Beaver, Butler, Fayette, Indiana, Somerset, and Westmoreland counties.

UPPER COAL MEASURES.

These often carry a thin seam of fire clay, which forms a parting in the Pittsburg coal seam.

Tennessee.—The fire clays occurring in the Tertiary formations of western Tennessee are worked locally for making fire brick, notably at Grand Junction and Pinson. The Carboniferous rocks contain many fire-clay beds, but most of them are undeveloped. The residual clay from the Knox dolomite is at times refractory and has been utilized for fire brick.

Virginia.—Fire clays are, no doubt, to be found in the Coastal Plain formations, and kaolins occur in the crystalline area. No fire clays have been reported from the Carboniferous rocks.

West Virginia.—Fire clays are known in the Pottsville conglomerate of the Coal Measures, as at Piedmont. Refractory clays are also found under the Upper Freeport and Kittanning coals, but they are not nearly so abundant as those of Pennsylvania or Ohio.

Wisconsin.—The clays derived from pre-Cambrian schists and Potsdam sandstones may be refractory, but they are not developed.

DESCRIPTION OF CLAY DEPOSITS, BY STATES.

ALABAMA.

Alabama is the only one of the Gulf States whose clay resources have been investigated in a systematic manner, and the investigations made show the presence of a great variety of materials that are of value in the fictile arts. The geologic map of the State shows a wide range of formations, nearly all of which carry valuable clay deposits.

ARCHEAN AND ALGONKIAN.

Archean and Algonkian rocks underlie a roughly triangular area in the eastern part of the State, the base of the triangle extending from near the northern border of Cleburne County southward to Russell County, and the apex being at Clanton, Chilton County. The rocks of this area are granites, gneisses, and schists, all of which may, by surface decay, furnish residual clay. The schist areas are, however, of additional importance, for they carry many pegmatite veins which have been

changed to kaolin in their upper part. A belt of mica-schists extends from Cleburne and adjacent parts of Randolph through Clay and Coosa into Chilton County.

The deposits, according to Dr. E. A. Smith, State geologist, lie near Milner, Pinetucky, and Micaville, in Randolph County, and Stone Hill, in Cleburne County.[a] At the present time these kaolins are undeveloped, as railroad facilities are lacking in that region.

The Alabama kaolins are rather siliceous, highly refractory, and burn to a very white color.

CAMBRIAN AND SILURIAN.

The clays obtained from these formations are either residual deposits or are concentrates from these, which have been carried by surface waters down into sinks and other depressions.[b] While the Silurian rocks contain some shaly members, these are not, so far as known, used for the manufacture of brick, but the residual clays are extensively employed for this purpose. These clays are usually rather impure, but in places may be quite free from impurities, as are those found near Gadsden, Etowah County; Kymulga, Talladega County; Peaceburg and Oaxanna, Calhoun County, and in Blount County. Indeed, these white clays sometimes form masses in the residual limonites, as in T. 15 N., R. 8 E., secs. 21 and 23. Another such deposit, a residual limestone clay, is in T. 14 N., R. 8 E., in Calhoun County.

In Cherokee County, north of the line of the Southern Railway, in secs. 1 and 2 of T. 12 N., R. 1 E, are many beds of limonite with horses of white clay. These have been tried at Chattanooga for fire-brick manufacture.

Accumulations of good clay are not uncommon in the depressions or sinks of the Cambro-Silurian limestone region. They are utilized at Oxford, Calhoun County, for pottery manufacture, and at De Armanville, in the Choccolocco Valley, for brick.

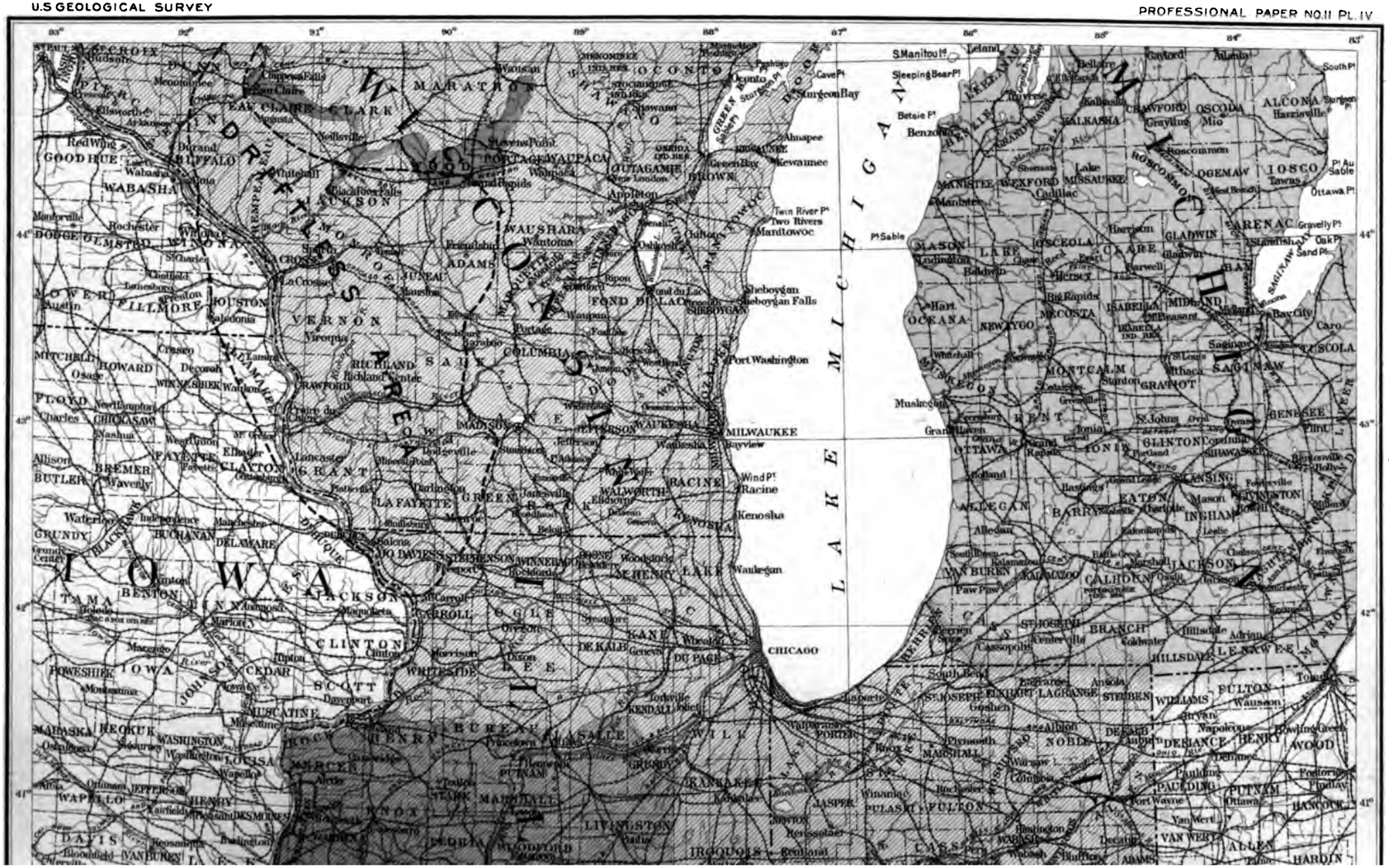
In the following table are given the physical and chemical characteristics of Alabama clays.

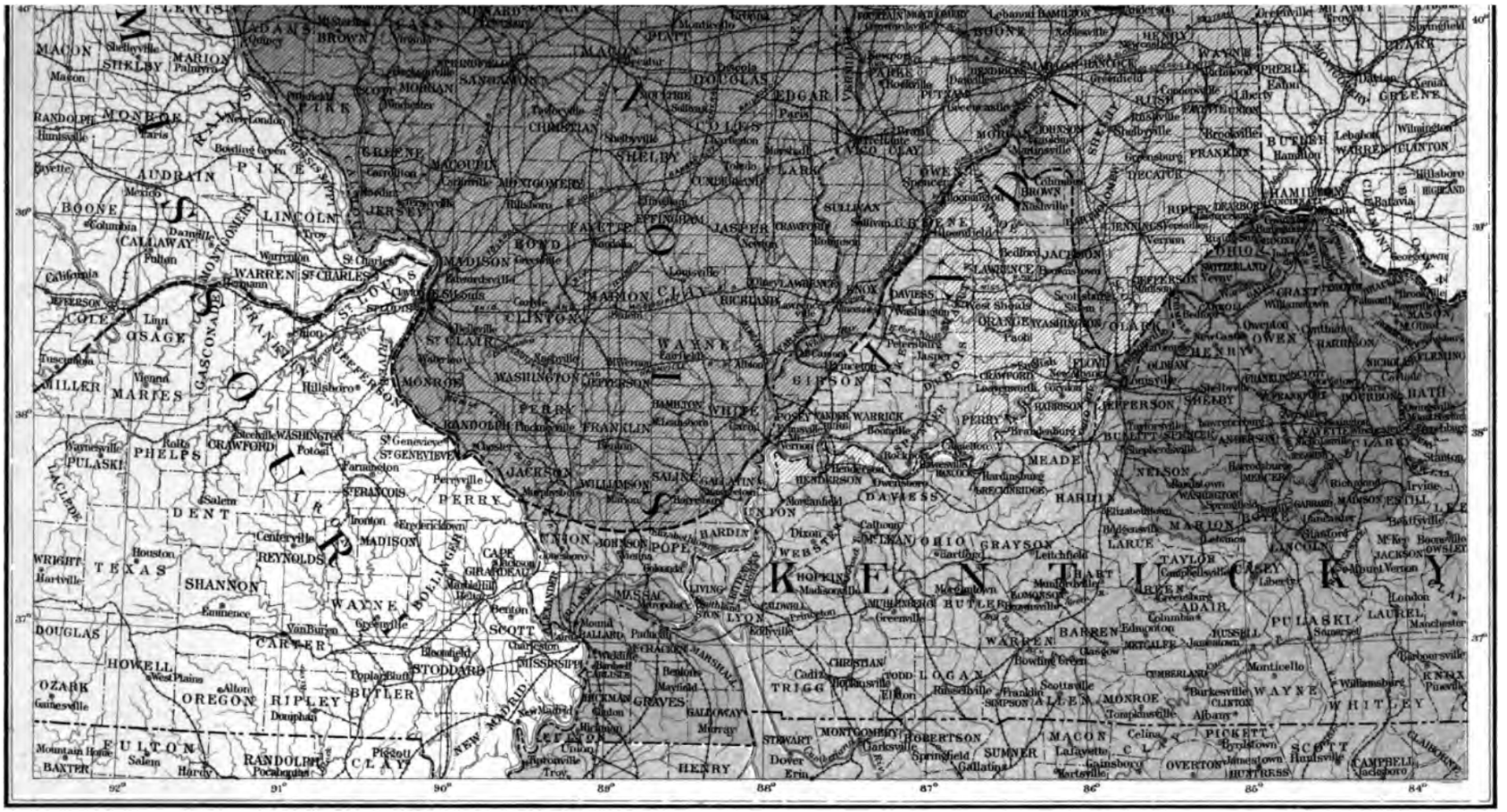
Physical and chemical characters of clays from Alabama.

Number.	Per cent water required.	Tensile strength.		Air shrinkage.	Fire shrinkage.	Incipient fusion.	Vitrification.	Viscosity.	Color when burned.	Variety.	Page of Bull. 6, Ala. Geol. Surv.
		Average.	Maximum.								
							Cone.	*Cone.*			
1	37.5	143	154	8	7	2,250	.....	27	Cream white	China clay...	121
2	25	20	25	5	8	2,250	30	.....	.....	Fire clay	135
3	16	9	10	2	2	+2,500	.....	.....	Buff	....do.	136
4	28	45	55	5	15	2,200	2,350	27	....do...	Stoneware ...	.....
5	26.75	130	144	10	8	2,200	2,400	2,600	....do...	.....	189

[a] Bull. Alabama Geol. Survey No. 6, p. 70.

[b] Ibid., p. 73.


LEGEND
Surface clays, chiefly for brick and drain tile
Stone-ware and fire clays
Shales and fire clays
Impure shales, paving brick, structural products, and impure surface clays
Impure residual clays, some calcareous shales
Terminal moraine
LAKE MICHIGAN
IOWA
ILLINOIS
INDIANA
MICHIGAN
WISCONSIN



MAP SHOWING DISTRIBUTION OF CLAYS IN MICHIGAN, WISCONSIN, ILLINOIS, INDIANA, AND KENTUCKY

Physical and chemical characters of clays from Alabama—Continued.

	1.	2.	3.	4.	5.
Silica	67.95	51.90	84.21	61.50	71.30
Alumina	20.15	35.00	9.75	26.20	17.16
Ferric oxide	1.00	.99	.69	2.10	1.94
Lime	1.00	.23	.70	.50	.60
Magnesia	Trace.	.10	.14	.43	.43
Alkalies	1.87	.55	.....	.70	.95
Ignition	8.00	11.30	4.10	7.29	7.60
Total	99.97	100.07	99.59	98.72	99.98

1. J. R. Hughes, Gadsden, Etowah County.
2. Peaceburg, Calhoun County.
3. Oaxanna, Calhoun County.
4. F. S. White, Blount County.
5. Oxford, Calhoun County.

LOWER CARBONIFEROUS.

This series underlies small areas in the northern portion of the State, but no mention is anywhere made of clays belonging to it. In Wills Valley, however, it contains one of the best-known deposits of white clay. It occurs in the lower strata of the series, close above the black Devonian shale. The deposits are found in the upper or northeastern end of the valley, and on both sides of it, although the most important is on the east side.[a]

The Red Mountain regions are made up of Clinton and Devonian rocks, and the clay occurs in the lower strata of the Lower Carboniferous, not far above the black shale, and is found to be present on both sides of the valley for 10 or 12 miles from the State line southward.

In the northwest corner of sec. 3, T. 6 N., R. 9 E., on the west side of the valley, the following section is exposed in a test pit:

Section in test pit in northwest corner of sec. 3, T. 6 N., R. 9 E., Alabama.

	Feet.	Inches.
Chert ledge weathered into sandy rock of yellow color		8–12
Strata hidden by débris	2–3	0
White clay without grit, in places like halloysite	3	0
Hidden	3	0
Devonian shale	25–30	0

[a] McCalley, H., Alabama Geol. Survey, Valley Regions, Pt. II, pp. 175–182, from which the description quoted is taken.

The white clay is locally known as chalk. Near the State line about Eureka station and thence southward for 2 miles the clay is worked in many places, having an aggregate thickness of about 40 feet, but thickens occasionally to 180–200 feet, of which as much as 60 feet are white clay. The clay is often mined by tunnels, and one of these mines is operated by the Montague Company of Chattanooga. The clays are refractory, as is shown by analyses and tests. Some beds of potter's clay have also been found in this formation.

Analyses and tests of Lower Carboniferous clays of Alabama.

	1.	2.	3.
Silica	82.04	79.80	66.25
Alumina	12.17	11.75	22.90
Ferric oxide	Trace.	1.75	1.60
Lime	Trace.	.75	Trace.
Magnesia	.327	Trace.	Trace.
Alkalies	.60	1.50	.75
Ignition	4.325	4.11	9.05
Clay substance	31.10	.....	40.70
Quartz	64.80	.....	47.90
Feldspar	3.90	.....	11.20
Water required.....per cent..	35	39	40
Plasticity	Lean.	Lean.	Lean.
Air shrinkage	.....	8	.....
Fire shrinkage	2	9	.....
Incipient fusion	2,400° F.	2,350° F.	2,300° F.
Vitrification	Cone 27	2,700	Cone 27
Viscosity	.....	Cone 27	.....
Tensile strength.....pounds..	5–6	20	.....
Color	Yellow.	Yellow.	Yellow.

1. Montague mines.
2. Valley Head.
3. Fort Payne, Dekalb County.

COAL MEASURES.

The Coal Measures occupy a large triangular area in the northern part of the State, and should prove to be of importance to the clay worker. The following counties are largely covered by them: Lawrence, Morgan, Jackson, Marshall, Dekalb, Cullman, Winston, Walker, Blount, Jefferson, Shelby. Unfortunately a large portion of this area lies remote from the railways, although it is traversed by the Northern Alabama and the Louisville and Nashville railroads.

The under clays in some parts of the coal fields have been employed for making

pottery, as at Jugtown, near Sterrit, in St. Clair County, and also at Fort Payne and Rodentown, in Dekalb County; Advance station, in Tuscaloosa County; Summit, in Blount County, and Arab, in Marshall County.

The shales are used in some parts of the State for making vitrified brick, especially at Coaldale. At the Graves coal mine, near Birmingham, there are two bodies of shale which are promising. Good exposures of Carboniferous shale also outcrop near Pearces Mills, in Marion County, and are probably well adapted for pressed brick or even terra cotta. No fire clays have been found in the Coal Measures.[a]

The following tests indicate the characters of some of these materials:

Analyses and tests of Carboniferous shales of Alabama.

	1.	2.	3.	4.
Silica	57.80	61.55	.....	.....
Alumina	25.00	20.25	.....	.....
Ferric oxide	4.00	7.23	.....	.....
Lime	2.10	Trace.	.....	.....
Magnesia	.80	.986	.....	.....
Alkalies	1.80	2.25	.....	.....
Water	7.50	6.19	.....	.....
Water required ..... per cent	25	20	22	40
Plasticity	Good.	Moderate.	Lean.	.....
Tensile strength	105	40	25	.....
Air shrinkage ..... per cent	2	1½	4	4
Fire shrinkage ..... do	10	5	5.5	5
Incipient fusion	2,000	2,000	1,900	2,100
Vitrified	2,200	2,250	2,150	2,300
Color	Red.	Red.	Red.	Red.

1. Gray shale, Birmingham. Alabama Geol. Survey, Bull. No. 6, p. 186.
2. Yellow shale, Birmingham. Ibid.
3. Shale, Coaldale. Ibid., p. 187.
4. Shale, Pearces Mills, Marion County. Ibid., p. 188.

CRETACEOUS.[b]

The Cretaceous formations are no doubt the most important clay-bearing beds in the State, and most of the deposits have thus far been found in one member of the Cretaceous, namely the Tuscaloosa. This consists usually of yellow and grayish sands, with smaller beds of pink and light-purple sands thinly laminated, dark-gray clays holding many leaf impressions, and gray lenses of massive clay which vary in color from yellow to almost pure white. This formation occupies a belt of country

[a] Bull. Alabama Geol. Survey No. 6, p. 80.

[b] Alabama Geol. Survey, Coastal Plain, Pt. I, p. 255.

extending from the northwest corner of the State around the edges of the Paleozoic formations to the Georgia State line at Columbus. Its greatest width is at the northwest boundary of the State, where it is 30 or 40 miles wide in Alabama and about the same width in Mississippi. From here the belt gradually diminishes in breadth toward the southwest, until at Wetumka and thence eastward to the State line it forms the surface along a belt only a few miles wide. East of the Alabama River the proportion of clay to the rest of the strata is less than in any other section, and at the same time the clays in this region are more sandy. From the Alabama River northwestward, in the gullies, ravines, and railroad cuts, there are many exposures of these belts exhibiting sections of clay beds from 6 to 50 feet thick and of varying degrees of purity. The purer clays have as yet been found in only the northern part of this area, in Fayette, Marion, Franklin, and Colbert counties, and in the adjoining parts of Mississippi.[a]

Some of the more important occurrences may be mentioned, beginning with the counties in the southeastern end of the Lower Cretaceous belt.

In Russell and Macon counties clays are exposed along the river flowing through Girard, in the hills west of the town, and mottled clays outcrop near Marvyn, Crawford, and Society Hill.

In Elmore and Autauga counties pottery clays are worked around Edgewood, the section at Chalk Bluff, Elmore County, being as follows:

Section at Chalk Bluff, Elmore County, Ala.

	Feet.
1. Lafayette red loam and pebbles	15
2. Gray and yellow sandy clays, irregular layers	6
3. White clay	3
4. Ocherous clay	3
5. Gray, plastic blue clay, with vegetable matter	10

North and northwest from Plattville there are many exposures, but they are rather sandy.

In Bibb County good exposures of massive clays are found between Randolph and Centerville, and again southwest of Centerville, in Ts. 21 and 22, Rs. 7 and 8.[b]

Additional good exposures occur along the Alabama Great Southern Railroad, as at Bibbville, where the clays have been used for fire brick, much clay being shipped to Bessemer from this locality. Other pits are at Woodstock, which lies to the north.

In Tuscaloosa many good exposures occur within the city limits, and some of them have been worked for pottery. The clays are exposed in ravines and along the Alabama Great Southern Railroad east of Tuscaloosa.

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[a] Local details of the Tuscaloosa formation in the counties of Pickens, Fayette, Marion, Franklin, Colbert, Lee, Russell, Macon, Lamar, Autauga, Cherokee, Perry, Bibb, and Tuscaloosa are given in the Alabama Geol. Survey, Coastal Plain, pp. 307-349, 531, 532, 536, 541, 549, 554, 556, 559.

[b] Ibid., p. 345.

The following section, 10 to 12 miles east of Tuscaloosa, illustrates the character of the formation:

Section 10 to 12 miles east of Tuscaloosa, Ala.

	Feet.	Inches.
1. Purple, massive clays	5	0
2. Ferruginous sandstone crusts	6–8	0
3. Variegated clayey sands, holding small pieces of purple clay.	10	0
4. Purple clays with partings of sand	10	0
5. Ferruginous crust	1	0
6. Laminated gray and yellow, sandy clay	6–8	0
7. Lignite with pyrite nodules	2	6
8. Dark-gray, somewhat massive clays	6	8
9. Strata obscured by débris from above	1	8
10. Purple clay at base of hill, thickness undetermined.		

In Pickens County clays are seen near the line of the Mobile and Ohio Railroad from the Tuscaloosa County line to near Columbus. Lamar County contains many deposits of clay underlying the surface red loam of the Lafayette formation, especially at Millport, Fernbank, between Fayette Court-House and Vernon, also at Buttahatchie Creek above Hunnels Bluff, and on Wilson Creek near Friendship Church. The clays show considerable variety.

Pottery clays have been worked one-half mile east of Sulligent and 6 miles north of Millville. The products from these compete with those made at Holly Springs, Miss.

Fayette County contains many beds of purple, gray, and white clay. The last-mentioned occur around the court-house.

The following section, 1 mile east of Concord Church, shows several beds of promising character:[a]

Section 1 mile east of Concord Church, Alabama.

	Ft.	In.
Red loam and sand of Lafayette formation	4	0
Ferruginous sandstone crust	0	2
White clay	6	0
Yellow sand	5	0
Variegated clay	2	0
Mottled red and white clay	3	0

Marion County[b] shows much Tuscaloosa clay, the materials being exposed in the cuts from Eldridge to Guin along the Kansas City, Memphis and Birmingham Railroad. Thick beds also outcrop around Glen Allen,[c] and white siliceous clays occur around Chalk Bluff and Pearces Mill, Marion County. (See No. 6 of the analyses.) Much clay also occurs near Bexar, and this closely resembles that used for pottery across the border in Mississippi.

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[a] Bull. Alabama Geol. Survey No. 6, p. 103.
[b] Alabama Geol. Survey, Bull. No. 6, p. 104, and Coastal Plain, pp. 331, 332, 333.
[c] Bull. Alabama Geol. Survey No. 6, pp. 104 and 105.

Colbert County contains fire clays, which have been worked near Pegram, on the Southern Railroad. The clay is obtained from the following section, exposed in the NW. ¼ sec. 34, T. 3 N., R. 15 W.

Section near Pegram, Ala.

	Feet.
1. Pebbles and sand	30
2. White clay	3
3. Small gravel	1
4. White clay	6
5. Sand and gravel	16
6. Yellow clay	6
7. White clay	1
8. Purple and black clay	10
9. Gray clay	5

Tests are given below of 4, 6, 8, and 9.[a]

Lauderdale County contains a bed of paint clay 10 feet thick, near the county line.

In the following table are given the physical tests and chemical analyses of a number of Lower Cretaceous clays, taken from Bulletin 6 of the Alabama Geological Survey. In each case the page on which the tests appear is given.

Analyses and tests of Lower Cretaceous clays of Alabama.

	1.	2.	3.	4.	5.	6.	7.
Silica	60.50	56.28	74.25	65.82	58.13	52.95	80.55
Alumina	26.55	32.50	17.25	24.58	24.68	35.10	10.50
Ferric oxide	.30	.20	1.19	1.25	3.85	.80	1.53
Lime	.90	Trace.	.40	.....	.15	Trace.	.34
Magnesia	.65	Trace.	Trace.	Trace.	.32	Trace.	Trace.
Alkalies	2.70	Trace.	.52	.60	1.78	.93	.....
Water	7.20	11.05	6.30	8.165	11.78	11.40	5.85
Moisture	.70	.20	.....	.....	.....	.....	1.70
Plasticity	Lean.	Lean.	Good.	Moderate.	Good.	Lean.	Lean.
Per cent H_2O required	30	25	22.6	23	36	37	28.6
Tensile strength	9	14	102	105	.....	.....	46
Air shrinkage	4	3	6½	7	12	4	10
Fire shrinkage	12	12	3½	11	6	.....	3
Incipient fusion	2,000	2,300	2,300	2,150° F.	2,200	Cone 27	2,150
Vitrification	.....	2,500	Cone 27	2,350° F.	Cone 27	Cone 30	2,350
Viscosity	.....	2,700+	.....	2,900° F.	.....	Cone 33	2,500
Color when burned	Whitish.	White.	Buff.	Buff.	Reddish.	Whitish.	Yellowish white.

[a] Bull. Alabama Geol. Survey No. 6, pp. 110, 130, 158; and Valley Regions, Pt. I., p. 180.

Analyses and tests of Lower Cretaceous clays of Alabama—Continued.

	8.	9.	10.	11.	12.	13.	14.	15.
Silica	60.38	.....	60.03	68.23	60.9	69.50	65.58	67.10
Alumina	20.21	.....	24.66	20.35	18.98	13	19.23	19.37
Ferric oxide	6.16	.....	3.69	3.20	7.68	6.40	4.48	2.88
Lime	.09	.....	.13	.34	Trace.	.25	Trace.	Trace.
Magnesia	.72	.....	.38	Trace.	Trace.	Trace.	Trace.	.725
Alkalies	1.80	.....	Trace.	.74	Trace.	Trace.	Trace.	.672
Water	10.21	.....	11.342	6.10	12.46	6.70	5.50	6.08
Moisture	.....	.....	.....	.....	.90	3.40	1.40	1.71
Plasticity	.....	Fair.	.....	Good.	Fat.	Good.	Good.	.....
Per cent H_2O required	38	36	31.5	21.8	45	32.6	34.3	25
Tensile strength	300–384	100	85	117	100	152	116	[a] 95 [b] 111
Air shrinkage	6	11	9	4	12.5	10	7	6.2
Fire shrinkage	7	7	8	8	6.5	7	6	5.8
Incipient fusion	2,100	2,100	2,100	2,000	1,900	1,900	2,000	2,000
Vitrification	2,200	2,300	2,200	2,200	2,100	2,100	2,200	.....
Viscosity	2,600	Cone 27	2,500	2,400	2,300	2,300	2,400	2,400
Color when burned	.....	Red.	Buff.	Buff.	Red.	Red.	Red.	Red.

	16.	17.	18.	19.	20.	21.	22.	23.
Silica	7[illegible] 20	67.50	66.45	71.32	.....	75.70	71.33	72.40
Alumina	17.42	19.84	18.53	20.10	.....	14.36	21.88	14.86
Ferric oxide	2.40	6.15	2.40	1.05	.....	4.64	.32	7.64
Lime	Trace.	.12	1.50	Trace.	.....	Trace.	.234	.20
Magnesia	Trace.	.10	1.25	.316	.....	Trace.	.305	.40
Alkalies	.56	1.50	Trace.	Trace.	.....	.....	.....	.....
Water	7.40	6.15	8.68	7.505	.....	4.45	5.54	5.05
Moisture	.12	.....	.78	.....	.....	1.24	1.05	.65
Plasticity	.....	.....	.....	.....	.....	.....	.....	.....
Per cent H_2O required	33	20	26	33	40	28	26	39
Tensile strength	[a] 106 [b] 123	[a] 102 [b] 127	[a] 30 [b] 35	.....	.....	[a] 45 [b] 53	[a] 66 [b] 68	[a] 55 [b] 80
Air shrinkage	10	10	5	6	6	6	6	6
Fire shrinkage	4	4	10	10	14	3	3	11
Incipient fusion	2,000	1,900	2,150	2,100	2,100	2,100	2,000	2,000
Vitrification	2,200	2,100	2,300	2,200	2,250	2,250	2,160	2,150
Viscosity	2,400	2,300	2,500	Cone 27	Cone 2	2,400	2,300	2,300
Color when burned	Buff.	Red.	Yellowish white.	Cream.	Brown.	Buff.	Buff.	Red.

[a] Average. [b] Maximum.

1. Rock Run, Cherokee County. Alabama Geol. Survey, Bull. No. 6, p. 119.
2. Pearces Mills, Marion County. Ibid., p. 130.
3. Bibbville, Bibb County; fire clay. Ibid., p. 151.
4. Elgin property, near Woodstock, Bibb County. Ibid., p. 153.
5. J. C. Bean, Tuscaloosa County; fire clay. Ibid., p. 154.
6. Pearces Mills, Marion County; fire clay. Ibid., p. 157.
7. J. W. Williams, Pegram, Colbert County. Ibid., p. 158.
8. Chalk Bluff, Elmore County; stoneware clay.
9. J. C. Bean, Tuscaloosa, Tuscaloosa County. Alabama Geol. Survey, Bull. No. 6, p. 170.
10. J. C. Bean, Tuscaloosa, Tuscaloosa County. Ibid., p. 171.
11. Roberts Mill, Coal Fire Creek, Pickens County. Ibid.
12. Cribbs's place, Bedford, Lamar County; pottery clay. Ibid., p. 173.
13. J. B. Green, Fernbank, Lamar County. Ibid., p. 174.
14. W. Doty, Fayette County; pottery clay. Ibid., p. 175.
15. W. Doty, Fayette County; pottery clay. Ibid., p. 176.
16. Shirleys Mills, Fayette County; pottery clay. Ibid., p. 178.
17. T. Rollins, Franklin County; pottery clay. Ibid., p. 181.
18. J. W. Williams, Pegram, Colbert County; pottery clay. Ibid., p. 182.
19. Shirleys Mills, Fayette County. Ibid., p. 190.
20. Chalk Bluff, Elmore County. Ibid., p. 191.
21. W. D. Bagwells, 7 miles north of Fayette Court-House, Fayette County. Ibid., p. 195.
22. H. Palmer, Bexar, Marion County. Ibid.
23. Bexar, Marion County; mottled clay. Ibid., p. 197.

TERTIARY.

The Tertiary formations underlie the southern third of Alabama. While it is known that they contain extensive deposits of clay, they have not been investigated.

A siliceous clay, resembling flint clay in appearance, is found in abundance in the counties of Choctaw, Clarke, Conecuh, etc., in the Lower Claiborne or Buhrstone division of the Tertiary. The composition of this flint is as follows:

Analyses of fire clay from Choctaw County, Ala.

	1.	2.
Silica	86.30	85.70
Alumina	5.12	6.15
Ferric oxide	1.60	1.80
Lime	.46	Trace.
Water	6.60	7.00
Total	100.08	100.65

PLEISTOCENE.

Over much of the Coastal Plain in the second bottoms of the rivers there is a great extent of yellow loam suitable for brick making. It corresponds in age to the

Columbia loams of the Northern States. No laboratory examination of it has been made.

CLAY-WORKING INDUSTRY.

Alabama ranked number 26 among the clay-producing States in 1900, and number 23 in 1901. In view of the variety of clays available this indicates a small development of the industry, due no doubt partly to lack of knowledge of the available raw materials and partly to absence of market. For the former reason it may be well, therefore, to group together the occurrences of the more important kinds of clay thus far described.

China clays.—The kaolins have already been collectively described on a previous page and need not be discussed again here.

Fire clays.—The fire clays of Alabama come from four geologic horizons, namely: (1) The Cambrian and Silurian limestone formations of the Coosa Valley region, seen at Peaceburg, Calhoun County, Oxanna, Calhoun County, and Rock Run, Cherokee County; (2) the cherty limestone of the Lower Carboniferous formations of Wills Valley, seen at Wills Valley and Valley Head, Dekalb County; (3) the Tuscaloosa formation of the Lower Cretaceous, occurrences being known at Bibbville and Woodstock, in Bibb County, Hull station and Tuscaloosa, in Tuscaloosa County, Potters Mills, in Marion County, and Pegram in Colbert County; (4) the Lower Tertiary formation, Choctaw County.

Very few of these deposits have been worked, but a number of them have been tested for the Alabama geological survey, as previously mentioned.

The refractory character of some of these Alabama fire clays can be judged from the following tests made on them in the Deville furnace:

Refractoriness of Alabama fire clays.

Locality.	Refractoriness.
Peaceburg, near Anniston	Vitrified at cone 30 and still retained its shape.
Rock Run, Cherokee County	Some bauxites vitrified at cone 30, while others showed only incipient fusion.
Fire clays from same place	Usually vitrified at cone 30.
Valley Head, Dekalb County, Montague mines	Incipiently fused at cone 27.
Second grade of fire clay, same mines	Viscous at cone 27.
Bibbville, Bibb County	Incipiently fused at cone 27.
J. C. Bean, Tuscaloosa County	Vitrified at cone 27.
Pearces Mills, Marion County	Vitrified at 30; became viscous at 33.

Clays suitable for the manufacture of pottery and stoneware are found at a number of places, among which are the following: Property of F. S. White, Blount County; C. C. Davenport, Rock Run, Dekalb County; McLean Pottery Company,

Coosada, Bedford, Fernbank, Lamar County; Cribb's pottery, Tuscaloosa, and J. C. Bean, Tuscaloosa County; Coal Fire Creek, Pickens County; Shirleys Mill, Fayette County; Pegram, Colbert County.

Brick clays.—Many deposits occur in the State, in several formations, among them the Carboniferous shales, Cambro-Silurian limestone residuals, and the second bottoms of the Coastal Plain.

Clay products.—Brick works are located at a great many places, chief among which may be mentioned Anniston, Bessemer, East Birmingham, Geneva, Mobile, Montgomery, North Birmingham, and Talledega. Fire brick are made in the vicinity of Birmingham, and at Anniston, Ashby, and Pegram. There are no fewer than 30 potteries scattered over the State, the products consisting of earthenware and stoneware. No white ware is manufactured in Alabama. The value of the clay products of Alabama has been as follows:

Value of clay products of Alabama in 1901.

Common brick	$742,691
Front brick	6,990
Fire brick	132,783
Miscellaneous	1,800
Red earthenware	1,030
Stoneware	17,252
Fire clay	15,758

Value of clay products of Alabama from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$301,341	28	0.46
1896	372,185	26	.60
1897	443,378	24	.71
1898	456,597	26	.63
1899	897,810	23	.94
1900	712,727	26	.74
1901	946,791	23	.86

CONNECTICUT.

CLAYS.

The clays of Connecticut are nearly all surface deposits of Pleistocene age, and hence are suitable only for the manufacture of structural products, drain tile, or the lower grade of pottery.

A deposit of kaolin, formed from the decomposition of feldspathic gneiss, occurs about 4 miles west of West Cornwall. It is washed and shipped to white-ware potteries. Indications seem to warrant the assumption that the deposit is very large. An analysis of the washed product is given below:

Analysis of kaolin from West Cornwall, Conn.

	Per cent.
SiO_2	47.50
Al_2O_3	37.40
Fe_2O_3	.80
CaO	Trace.
Alkalies	1.10
H_2O	12.48
Total	99.28
Clay substance	99.00
Quartz	1.00
Total	100.00

The material is very refractory, its fusing point lying above cone 27.

CLAY-WORKING INDUSTRY.

Many common brick are made in Connecticut from surface clays, especially around Berlin, Hartford, New Haven, and Middletown. Fire brick are produced at New Haven from New Jersey clays. Some pottery is also manufactured.

The total value of the clay products of Connecticut and Rhode Island[a] from 1895 to 1901 was as follows:

Total value of clay products of Connecticut and Rhode Island from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$831,925	20	1.27
1896	1,151,598	11	1.85
1897	1,336,670	10	2.13
1898	952,180	16	1.32
1899	1,074,202	20	1.12
1900	1,099,972	20	1.14
1901	1,130,909	21	1.03

[a] Rhode Island is included in the Geological Survey statistics after 1897, and hence it is necessary to give the two together.

DELAWARE.

CLAYS.

Little has been published regarding the clay resources of this State. In its northwestern part, along the Pennsylvania boundary, deposits of kaolin similar to those found in southeastern Pennsylvania have been worked for a number of years at Hockessin and Newark, Del. The product is washed before shipment.

The Potomac beds of the Coastal Plain area are said to contain stoneware and fire clays, and have been worked at one or two localities not far from Wilmington to supply the chemical stoneware works at Philadelphia.

J. C. Booth, in his Memoir of the Geological Survey of Delaware (1841), refers to a red-clay formation which shows well in the borders of Christiana Creek, where it forms hills rising to 60 or 80 feet above tide. It is mostly red, but contains occasional veins of white clay. It is stated to be of value at one locality on the Delaware shore below Newcastle.

CLAY-WORKING INDUSTRY.

Delaware is of little importance as a producer of clay products. The total value between 1895 and 1901 is given below:

Value of clay products of Delaware from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$58,615	41	0.09
1896	61,003	41	.10
1897	68,458	40	.11
1898	90,555	39	.13
1899	168,485	38	.18
1900	156,274	39	.16
1901	131,164	40	.12

DISTRICT OF COLUMBIA.

CLAYS.

A small but energetic local industry is based on clays derived from the Coastal Plain formations of this area. According to Darton,[a] there is an abundance of brick clay in the vicinity of Washington, and much of it is used. The clays worked are

[a] Geologic Atlas U. S., folio 70, Washington, D. C.

chiefly of later Columbia age, but at the intersection of Bladensburg road and Florida avenue extensive excavations have been made in sandy Potomac clays.

The chief workings in Columbia loams are on the west side of the Potomac River, between Washington and Alexandria, and just south of Alexandria.

In the eastern part of Washington wide areas have been stripped of a thin layer of loam for brickmaking. The upper loam is suitable for brick over the greater part of the wide later Columbia terraces adjoining the Potomac River. On the smaller areas along creeks and on the terraces adjoining the greater part of the Anacostia River the deposit is usually too sandy for working.

The sandy clays of the Potomac are often suitable for brickmaking, and have been used to some extent. On the wider terraces of earlier Columbia and Lafayette formations are many local areas of loam which are available. Other sources of supply are detrital clays and alluvium from crystalline rocks.

The Potomac clays are worked for tiles at Terra Cotta, University station, and Lamond, on the Metropolitan Branch of the Baltimore and Ohio Railroad. Many masses of these clays occur, especially east of the Anacostia River.

CLAY-WORKING INDUSTRY.

The value of the clay products of the District of Columbia each year since 1895 is as follows:

Value of clay products of District of Columbia from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$373,304	27	0.57
1896	353,565	28	.57
1897	288,981	30	.46
1898	320,320	30	.45
1899	481,145	33	.50
1900	288,933	35	.30
1901	324,008	35	.29

FLORIDA.

The clays of Florida are mostly surface deposits of Tertiary or Pleistocene age, and occur chiefly in the northern part of the State. Very little has been published regarding them. The following facts are taken mostly from published notes made by the writer several years ago.[a]

[a] Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. III (continued), p. 875.

Brick clays are of common occurrence in Florida, especially in the northern half of the State, but they are often sandy and are worked on only a small scale at many localities. A large pit has been opened at Jacksonville for brickmaking. Other plants are at Ocklocknee, west of Tallahassee, Bartow, Leesburg, etc.

BALL CLAY.

Florida is one of the few States producing this material. It occurs at several points in the north-central portion of Florida (Pl. IX), and the different areas may represent portions of a formerly continuous bed. It is undoubtedly of sedimentary origin, and the occurrence of such an extensive deposit so free in most places from impurities is remarkable. The mass is made up of a mixture of white clay and quartz pebbles, the latter forming 65 to 75 per cent of the entire mass, so that for every ton of washed clay about four tons of the crude material have to be mined. The quartz pebbles vary in size from that of a pin head to a diameter of three-quarters of an inch. The largest ones seem to occur chiefly at the northern end of the area in which the kaolin is found. If the deposits were nearer to the pottery centers, or if freight rates were lower, the pebbles could no doubt be ground for potter's use. The largest pit which was being worked at the time of the writer's visit was that at Edgar, Fla., (Pl. I, *A*), which is about 50 miles southwest of Jacksonville. The section in the pit at this locality was as follows:

Section in clay pit at Edgar, Fla.

	Feet.
Top soil	8
Impure upper clay	8–10
White clay	25
Green clay.	

The thickness of the green clay is not exactly known, but at other localities it is seen to rest on limestone.

Another but more extensive area of this clay occurs along the Palatlakaha River, south of Leesburg, Lake County. This large clay tract begins 1 mile south of Lake Harris, into which the Palatlakaha River flows, and extends along both sides of the river nearly to Villa City. Throughout this belt there is an overburden of about 3 feet of loose sand, under which lies the white ball clay, of a depth varying from 10 to 30 feet. It is frequently well exposed in the bluffs along the river. This deposit has been opened up at a point about 4 miles south of Leesburg, where it is said to be 25 to 30 feet thick.

Another area of this same clay occurs at Bartow Junction, Polk County, about 45 miles northeast of Tampa.

The sandy character of the raw clay permits its being worked by a method somewhat different from that usually practiced at most kaolin mines. At Edgar

the pit is filled with water, and on this there is a float carrying a scraper and pump. The former loosens up the clay in the bottom of the pit and the latter draws it up to the surface and discharges the water, with suspended clay and sand, into the washing troughs.

Owing to the fact that this Florida clay is very plastic it is put on the market under the name of ball clay. It is very refractory and burns white. In the table below are given chemical analyses of the clay from different points. It differs from the English ball clay chiefly in its greater refractoriness, and also somewhat in its plasticity. The shrinkage of it at cone 8 is stated by Langenbeck to be 15 per cent.[a]

Analyses of Florida ball clay.

	1.	2.
Silica	46.11	45.39
Alumina	39.5	39.19
Ferric oxide	.35	.45
Lime	.....	.51
Magnesia	.13	.29
Alkalies	.....	.83
Water	13.78	14.01
Sulphur trioxide	.07	.....
Total	99.94	100.67

1. Washed clay from Palatlakaha River.
2. Washed clay from Edgar.

According to Mr. T. W. Vaughan, of the United States Geological Survey, who has been doing field work on the Tertiary formations of northern Florida and southwestern Georgia, another deposit of ball clay occurs on the land of Mr. Augustus Munroe, sec. 32, T. 10 S., R. 23 E. Mr. Vaughan states that—

"The material is very sandy, but its thickness could not be ascertained from observation. Several auger holes had been sunk, and these indicate a thickness of about 10 feet. The bed is said to be thicker near the summit of the hill. The overburden varies from 4 to 10 feet, and the deposit can be economically worked over an area of several acres. The transportation facilities are good, as the Plant System railway is only a half mile distant."

Mr. Vaughan has supplied a number of data regarding the clays in that region, which are given below.

White calcareous clay outcrops on the land of W. B. Stoutamire, 18 miles southwest of Tallahassee, Leon County, and three-quarters of a mile north of his house. The outcrop is on a hillside in sec. 1, T. 1 S., R. 4 W.

[a] The Chemistry of Pottery, p. 101.

The chemical composition of the clay is indicated by the following analysis:

Analysis of clay from Leon County, Fla.

[Analyst, H. Ries.]

	Per cent.
SiO_2	35.95
Al_2O_3	13.23
Fe_2O_3	1.27
CaO	15.00
MgO	5.40
H_2O ... Moisture	10.55
CO_2	18.50
Total	99.90

Brick clay crops out on the property of J. D. Stoutamire, in sec. 15, T. 1 S., R. 4 W. A physical examination of this clay shows it to be very plastic and to absorb 40 per cent of water in being worked up. It has a large air shrinkage—17 per cent—and when being burned up to cone 05 its fire shrinkage is 4 per cent, and up to cone 2 its fire shrinkage is 5 per cent. Its tensile strength is very good, ranging from 175 to 210 pounds per square inch. The clay is peculiar in that it burns to a very light-buff product, due apparently to a low percentage of iron oxide, and not to the presence of carbonate of lime. Incipient fusion occurs at 05, and the clay burns to a hard, dense product at cone 2. If mixed with sufficient sand to prevent its shrinking so much in burning, it could, very probably, be utilized in the manufacture of light-colored front brick. It does not show the same tendency to crack in drying that the sample from Climax, Ga., does. Owing to its light color, the soluble salts, if present, did not tend to show themselves.

Another locality at which calcareous clay was found is on the land of Mr. W. W. Williams, about one-half mile southeast of Jackson Bluff, on the Ochlockonee River, in sec. 21, T. 1 S., R. 4 W. The outcrop occurs in the bed and along the sides of a small creek. The material is overlain by about 6 feet of sandy alluvium, and 2½ feet of clay is exposed. The chemical composition is given below:

Analysis of calcareous clay from the land of Mr. W. W. Williams, near Jackson Bluff, Ochlockonee River, Fla.

[Analyst, H. Ries.]

	Per cent.
Silica	30.83
Alumina	15.40
Ferric oxide	1.40
Lime	13.78
Magnesia	7.50
Alkalies	Undetermined.
Carbon dioxide	20.14
Water	7.16
Total	96.21

This clay behaves very differently from most calcareous clays and may possibly contain some silica in the hydrous form, which perhaps accounts for its great shrinkage in burning. The bricklets made from it took 45 per cent of water to work them up, and the mixture had an air shrinkage of 16 per cent. Although this was not of very plastic feel, yet its tensile strength was very high, averaging 338 pounds per square inch, with a minimum of 300 and a maximum of 388. When burned to cone 05 the fire shrinkage was 5 per cent. The bricklet was still scratched with a knife and was very absorbent. At cone 01 the fire shrinkage was 7 per cent, the bricklet still absorbent and barely scratched with the knife. At cone 1 the fire shrinkage remained the same, the hardness about the same, and the color was creamy. At cone 3 the fire shrinkage was 7 per cent, the color light buff, and the bricklet was very absorbent. At cone 5 the fire shrinkage was 12 per cent, the color reddish buff; the bricklet could not be scratched by a knife, but it had not yet vitrified. It seemed to vitrify at about cone 6. Up to this point it held its form, but when heated up to cone 8 it rapidly became viscous and went to a slaggy mass of yellowish color. The clay behaves peculiarly for a calcareous one, and the writer expects, therefore, to examine it a little further and to report more fully on its peculiarities. It could not be used alone in the manufacture of clay products on account of its high shrinkage, but no doubt it would make excellent binding material if mixed in with another clay.

CLAY-WORKING INDUSTRY.

The total value of the clay products of Florida for each year from 1895 to 1901 was as follows:

Value of clay products of Florida from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	114,015	39	0.17
1896	122,144	39	.20
1897	89,435	38	.14
1898	130,987	38	.17
1899	138,808	41	.14
1900	140,604	40	.15
1901	190,674	39	.17

Value of clay products in Florida in 1901.

Common brick	$185,759
Front brick	(a)
Drain tile	1,515
Sewer pipe	(a)
Miscellaneous	2,500
Ball clay	(a)

GEORGIA.

Georgia is divisible, geologically, into three areas, viz: (1) A northwestern area, underlain by rocks of Paleozoic age, consisting of shales, limestones, and sandstones; (2) a central broad belt of pre-Cambrian rocks, such as granites and gneisses; (3) a southeastern belt, in the Coastal Plain region, composed of unconsolidated sedimentary rocks of recent geologic age—Cretaceous, Tertiary, and Pleistocene.

PALEOZOIC AREA.[b]

This belt includes the counties of Polk, Floyd, Barton, Gordon, Murray, Whitfield, Catoosa, Chattooga, Walker, and Dade. In this area the rocks range from the Cambrian to the Carboniferous, inclusive, with the exception of the Lower Cambrian[c] and Upper Ordovician beds.

The general section involves the following formations:

Carboniferous formations of Georgia.

Carboniferous	Walden sandstone.
	Lookout sandstone.
	Bangor limestone.
	Floyd shales.
	Fort Payne chert.
Devonian	Chattanooga shales.
Silurian	Rockwood shales and sandstones.
	Chickamauga limestone.
	Knox dolomite.
Cambrian	Conasauga shale.
	Rome sandstone.

The thickness of this section is considerable, but is difficult to determine accurately because the strata have been much folded and have also been displaced by extended faulting. It can be said, however, that the different formations extend across the northwestern part of the State in a northeast-southwest direction, and that within the area occupied by them they furnish both residual clays and shales. The residual clays have been derived by decomposition from various types of rocks, including sandstones, shales, and limestones, and the general product of weathering

[a] Less than three producers.

[b] Spencer, J. W., The Paleozoic group: Georgia Geol. Survey, 1893. Also Geologic Atlas U. S., folio 2, Ringgold

[c] Spencer, J. W., ibid., pp. 28-29.

is a ferruginous clay, which may vary in siliceousness and plasticity, the degree of these depending on the character of the parent rock, etc.

The impure residuals[a] may be derived from calcareous Paleozoic shales.

In places the limestones may be decayed to a depth of 22 feet.[b]

The residual earths from the limestones run as follows in composition:[c]

Composition of residual earth from limestone.

	Per cent.
Silica	64–84
Alumina	6–15
Ferric oxide	3–10

The Knox dolomite and Chickamauga and Bangor limestones are important sources of residual clays, and while these are commonly rather impure, pockets of white material may occur which may yield clay suitable for fire brick. The clay deposits are often large. In the cherty remains of other portions of the Knox dolomite the siliceous nodules are embedded in white, siliceous, chalky clay, as near Cave Spring, or in the Lookout Valley in Fort Payne chert. The siliceous matter could probably be separated by washing. At Woodlands a fine quality of clay is said to exist.

The following two analyses show the composition of these residuals:

Analyses of white residual clays from northwest Georgia.

	1.	2.
Silica (combined)	40.40	20.10
Silica (free sand)	.80	46.10
Alumina	38.60	15.41
Ferric oxide	1.45	6.06
Lime	.....	.....
Magnesia	.30	1.29
Potash	.09	4.55
Soda	.02	.34
Titanic acid	1.95	1.35
Water	16.35	4.75
Moisture	.35	.20
Total	100.31	100.15

1. Clay from bauxite beds on Flowery Branch, Floyd County.
2. Clay from a "horse" in the iron-ore beds at Grady.

These clays are probably refractory, judging from the character of the bauxite at Rock Run, in adjacent territory in Alabama.

[a] Spencer J. W., The Paleozoic group: Georgia Geol Survey, 1893, p. 282. [b] Ibid., p. 22. [c] Ibid., p. 23.

The following analyses of Paleozoic shales, given by J. W. Spencer, will show their composition:

Analyses of Paleozoic shales and clays from Georgia.

	1.	2.	3.	4.
Silica (combined)	9.30	19.40	52.82	69.33
Silica (free)	62.30	39.20		
Alumina	11.50	18.05	26.17	19.01
Ferric oxide	5.59	8.31	9.46	2.02
Lime			Trace.	Trace.
Magnesia	1.30	1.55	1.08	.87
Potash	4.20	4.63	2.71	2.10
Soda	.35	.33	.20	.18
Manganese dioxide	.60			
Titanic acid	1.10	.68	(a)	(a)
Water	3.80	7.60	7.00	6.88
Moisture	.15	.40	.23	.26
Total	100.19	100.15	99.67	100.65

a Included with alumina.

1. Light-colored hydromica shale in ridge above Etowah iron bridge south of Cartersville.
2. Light-red shale, 1 mile southwest of Cartersville, of Oostanaula series.
3. Less calcareous clay of same series 2 miles northwest of Cartersville.
4. Light-colored plastic clay, from near head of McLamore's cove, of Lower Carboniferous age.

PRE-CAMBRIAN BELT.

This covers an area of about 12,000 square miles, and consists of granites, gneisses, schists, and marbles, and in places pegmatite veins. The latter should afford kaolin, and throughout the region residual clays are abundant. The wash from them may form secondary deposits in the valleys.

COASTAL PLAIN REGION.

The Coastal Plain district of Georgia includes that portion of the State lying southeast of a line drawn through Augusta, Macon, and Columbus, these towns being along the "fall line" which represents the boundary between the older and younger formations of the State. In this area the formations range from Cretaceous to Pleistocene, and contain many clay deposits of varying character, ranging from the impure, easily fusible clays to snowy white clays of high refractoriness. The general character of most of the deposits is that of a lens-shaped mass surrounded by sand or sandy clay.

The Cretaceous occupies the smallest area at the surface, consisting of a triangle, of which the base is on the Chattahoochee River, the apex is at Macon, and the northwest side coincides approximately with the fall line. It includes, however,

the most important clays found along the fall line in Georgia, representing the Potomac series. The Cretaceous section shows considerable thickness, for in following down the Chattahoochee River from Columbus about 1,640 feet of Cretaceous beds are seen, affording an excellent opportunity for studying their character. A belt of clays occurs near the base of the Georgia Cretaceous section, and these have been traced across the State into South Carolina.[a]

The Eocene and Miocene beds of the Tertiary overlap the Cretaceous beds to the south and east and extend to the coast. Both the Cretaceous and the Tertiary, however, are covered by a mantle of Lafayette and Columbia sands, gravels, and clays, which may at times so effectively conceal the older beds that they are seen only in railroad cuts, ravines, or hillsides.

CRETACEOUS.

Within the triangular area mentioned above the Cretaceous is well exposed in cuts along the Central Railroad of Georgia, especially between Columbus and Macon; and for a number of miles east of Macon along the railroad there are many exposures of white clays and sands. The region around Griswoldville, 10 miles east of Macon, contains the best Potomac clays along the fall line. It includes the southern half of Jones and Baldwin counties and the northern half of Twiggs and Wilkinson. According to Ladd, clay is exposed at many points on the property of J. R. Van Buren & Co., especially in the railroad cuts and gullies along the terrace followed by the Central Railroad. The clays of this region are from 6 to 10 feet thick, often white in color, free from grit, and have a soapy feel, for they contain many muscovite scales of microscopic size. Some of these clays have been shipped to Chattanooga for use in the manufacture of fire brick.

Thick beds of white clay also occur at Lewiston, east of Griswoldville, and are mined for wall paper and encaustic tiling. The product, after mining, is separated into three grades—white, yellow, and spotted. The following section, exposed in the eastern pit at this locality, may be regarded as fairly typical:

Section in pit at Lewiston, Ga.

	Feet.
1. Red and yellow clayey sand, with seams of laminated clay; also thin seams of brown iron ore containing coarse pebbles	6
2. Irregular siliceous beds resembling quartzite, and containing drusy quartz cavities and many fragments of shells	4
3. White sand, free from iron stain, cross bedded in places, containing mica and kaolin, and also nodules and fragments of white clay, in the upper surfaces of which are sharply outlined pear-shaped cavities, each filled with a yellowish clay. These cavities vary in diameter from one-fourth to one inch	7
4. White clay free from grit	2
5. White sand at bottom.	

Another deposit occurs 1½ miles east of Lewiston, on the property of J. J. Whitehurst, the clay there being 8 to 10 feet thick, with 6 to 8 feet of stripping.

[a] Ladd, G. E., The clays of Georgia: Bull. Georgia Geol. Survey No. 6, p. 80.

There are many pits of Potomac clay 2½ miles south of Gordon, on the E. J. Massey estate, along the northern base of the ridge, but in most places they are overlain by a great thickness of Tertiary clay and Orange sands. Outcrops of Potomac clays also occur around McIntyre, and at a point 1½ miles south of Dry Branch, a station on the Macon, Dublin and Savannah Railroad in Twiggs County. Here the clay, which is similar to that at Lewiston, is 15 feet thick, and mostly white. West of Fitzpatrick and between there and Bullards station are similar occurrences of Potomac clay. Potomac clays are also found west of the city of Augusta; around Grovetown, Columbia County, and 3 miles south of the same locality. They are also traceable eastward from Columbus, and range from mottled to pure white. They are overlain by Lafayette and Columbia. At Butler the clay is from 20 to 25 feet thick and is mined for paper. In Crawford County the Potomac clays are used in the manufacture of common pottery, while around Macon they crop out on both sides of the river.

From the following table, giving the chemical and physical properties of some of these clays, it will be seen that they run low, usually, in fluxing impurities, and hence are highly refractory. Their tensile strength in most cases is rather low. They are used for paper manufacture, pottery, and encaustic tiling. The paper clays have to be washed for shipment.

Analyses and physical characters of Coastal Plain clays in Georgia.

	1.	2.	3.	4.	5.	6.	7.
Moisture	0.57	0.99	0.21	1.91	8.7	0.72	3.64
Ignition	13.08	12.98	14.52	13.39	11.24	13.64	19.41
Combined SiO_2	44.94	44.92	42.79	43.08	54.39	43.85	13.62
Al_2O_3	39.13	39.13	40.42	40.63	14.64	38.28	11.56
Free SiO_2	1.23	1.55	.82	1.94	1.89	2.77	36.80
Fe_2O_3	.45	1.05	.70	1.01	.28	1.02	2.2
CaO	.18	.40	.37	.16	7.08	.18	13.89
MgO	.11	.17	.....	.00	1.71	.....	1.73
K_2O	.51	Tr.	Tr.	.27	4	.05	Tr.
Na_2O	.63	Tr.	.83	Tr.	23	.08	1.36
Absorption	112	.....	80	.....	200	100	98
Air shrinkage	.8	.9	8	8	25	8	18–20
Tensile strength	25	19	Under 10	12–15	213	24	143 304 255
Cone of fusion	36	36	36	35–36	.....	35	.....
Specific gravity	1.76	1.5 1.9	1.89 1.94	1.72 1.89	.9 1.2	1.69 1.75	1.8 2
Color when burned	.....	White.	.....	White and pinkish.	Buff to pale yellow.	.....	.....
Fire shrinkage	.....	.....	4	0	6	2	2

1. J. R. Van Buren & Co., Griswoldville. Bull. Georgia Geol. Survey No. 6, p. 108.
2. Lewiston Clay Works. Ibid., p. 115.
3. Z. T. Miller property. Ibid., p. 126.
4. Payne and Nelson pit near Macon, Twiggs County. Ibid., p. 133.
5. Tertiary clay, 1 mile east of Fitzpatrick. Ibid., p. 135.
6. Fire clay, Stevens Pottery, Georgia. Ibid., p. 139.
7. Summit.

Clays 1–6 are Potomac clays (Cretaceous); clay 7 is Tertiary.

The following notes on Cretaceous clays of Georgia have been supplied by Mr. T. Wayland Vaughan, of the United States Geological Survey:

Clay is well exposed on the Plant System Railway 1 mile west of Climax, Ga. The bottom of the section is about 23 feet below the level of the railroad, and the top of it is 30 feet above. The section is as follows:

Section 1 mile west of Climax, Ga.

	Feet.	Inches
15. Soil and humus. From a few inches to a foot or more.		
14. Yellowish sands, small gravel	6	0
13. Mottled sands and clay	5	0
12. Sands and some clay, showing distinct stratification, whitish, yellowish, and reddish.. (The upper 20 feet cross bedded. There is some ferruginous sandstone.)	25	0
11. Clays, blotched reddish (About 2 feet below the level of the railroad.)	5	0
10. Stratified sands and clays, blotched red	6	0
9. Stiff clay, blotched red	2	0
8. White sands with seams of clay	3	0
7. Stiff blue clay, blotched red	1	3
6. Finely laminated sand and clay	1	0
5. Bluish clay (specimen collected)	1	0
4. Whitish sands	3	6
3. Blue clay	2	0
2. Whitish sands, little clay	0	9
1. Fine sandy bluish clay	1	6

The clay from this point is reddish, and is doubtless suitable for the manufacture of brick. It is exceedingly fine grained and on this account takes up considerable water in mixing, the amount being 40 per cent. A number of bricklets and briquets were made from this mixture, and the former in drying showed a total shrinkage of 17 per cent, which was sufficient to induce cracking in the clay. On this account it would have to be more or less thoroughly mixed with sand. The clay contains a large proportion of soluble salts, and in the process of air drying these form a white scum on those surfaces and edges of the bricklet from which the water evaporates most rapidly. The tensile strength of air-dried briquets ranged from 140 to 180 pounds per square inch, but in most cases they probably broke before the actual limit of strength was reached, by reason of the formation of incipient cracks in drying.

The clay burns to a red color at a very low temperature—cone 05—and at this point is dense and hard, showing a total shrinkage of 18 per cent. Most common brick clays would not show a shrinkage of more than 10 per cent up to this point.

Clay from Cohn tobacco plantation.—The clay used on the Cohn & Co. tobacco plantation in the manufacture of brick for use in buildings, etc., on the plantation took the same quantity of water as the clay just described to mix it up, and its air shrinkage was 15 per cent, but it showed less scum on the surface, due to soluble materials in the clay. At cone 05 the clay burns to a good red color, with a fire shrinkage of 2 per cent, which is less than that of the other two samples. There were a few small cracks.

When burned to cone 2 the color was a much deeper red, and the fire shrinkage 5 per cent, while the brick was dense, though not vitrified. It also cracked somewhat, due to the high shrinkage.

The tensile strength of the air-dried briquets made from the clay was high, ranging from 260 to 300 pounds per square inch, with an average of 270 pounds.

This clay would also need to have sand mixed with it in molding, but owing to its high tensile strength could no doubt take considerable of this material.

TERTIARY CLAYS.

The Tertiary clays, though probably more extensive than those of the Cretaceous, are not so well known.

Ladd[a] mentions their occurrence around Fitzpatrick and 1 mile east of that place. A Tertiary outlier occurs 6 miles northwest of Griswoldville, and is well exposed in the railroad cut at Summit. It is a bluish or greenish, more or less laminated clay, of calcareous character, melting at 1,106° C. It is used with Potomac clays, and Ladd suggests that it may be used for the manufacture of paving brick. Beds probably of Tertiary age are also known in the railroad cut east of Grovetown station.

COLUMBIA CLAYS.

These are widespread in the Coastal Plain region. They are worked around Hudson, and also in the terraces around Macon, where they are employed for making brick and sewer pipe.

Additional beds are worked for brick around Augusta, and at Milledgeville. This latter deposit is at least 10 feet thick.

According to Spencer[b] most of the bricks manufactured in northwestern Georgia are made from alluvial clays. Good material for this purpose is found along the Etowah River at Cartersville. This is less fusible than the same class of material

[a] Ladd, G. E., The clays of Georgia: Bull. Georgia Geol. Survey No. 6, p. 135.
[b] Spencer, J. W., The Paleozoic group: Georgia Geol. Survey, 1893, p. 286.

worked at Rome, but the latter is said to make a better brick. The following analyses indicate the composition:

Analyses of Columbia brick clays from Georgia.

	1.	2.	3.
Silica (combined)	69.18	17	14.30
Silica (free)	.....	50.80	63.30
Alumina	15.43	13.82	10.90
Ferric oxide	5.83	5.74	2.25
Lime	.....	.....	.....
Magnesia	.71	.81	.63
Potash	1.83	2	1.83
Soda	.15	.55	.32
Titanic acid	.....	1.67	1.98
Water	6.61	7.35	4.70
Moisture	.22	.25	.20
Total	99.96	99.99	100.41

1. Brick clay from Cartersville, on Etowah River.
2. Surface clay at Rome.
3. Lower clay at Rome, 10 feet below surface.

CLAY-WORKING INDUSTRY.

Georgia in 1901 ranked sixteenth among the clay-producing States, having gained considerably in the last six years. The value of the clay products has been as follows:

Value of clay products of Georgia from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$867,355	15	1.33
1896	904,813	15	1.46
1897	962,513	14	1.54
1898	857,258	18	1.20
1899	1,263,995	15	1.32
1900	1,193,218	17	1.24
1901	1,545,083	16	1.40

The values of the various clay products in 1900 and 1901 were as follows:

Value of clay products of Georgia in 1900 and 1901.

	1900.	1901.
Common brick	$982,083	$1,182,533
Front brick	49,800	55,700
Terra cotta	66,000	71,800
Fireproofing	35,450	(a)
Sewer pipe		151,500
Vitrified brick		(a)
Drain tile		(a)
Fire brick	35,502	35,000
Pottery	21,033	17,230
Clay	32,645	44,315

[a] Less than three producers; hence not given.

Common brick are made from the residuals of the Bangor and Chickamauga limestones in the northwestern corner of the State, much clay having been dug near Blowing Springs. The calcareous Cambrian shales have been worked for the same purpose at a point 4 miles south of Lafayette.[a] Common brick, and even pressed and paving brick, are made from alluvial clays found in the valleys at Rome, Macon, and elsewhere, and the Coastal Plain clays are likewise worked for structural products. Fire brick, sewer pipe, and pottery are produced in limited quantities from the Potomac clays along the fall line. Stephens Pottery, at Stephens Pottery post-office, is the chief factory. Some of these clays are suitable for paper manufacture and are shipped to factories in other States. A valuable deposit of clay has recently been exploited in the southeastern portion of the State for use in roofing-tile manufacture.

ILLINOIS.[b]

The clay materials of this State come from the Ordovician, the Coal Measures, and the drift.

ORDOVICIAN.

This is probably of little importance, but the Cincinnati shales are recommended for pottery or brickmaking,[c] where they outcrop in Daviess and Boone counties.

COAL MEASURES.

The Coal Measures underlie a large area in the central, eastern, and southern portions of the State, within a line passing from Hampton, in Rock Island County, to the

[a] Geologic Atlas U. S., folio 2, Ringgold.
[b] See Worthen, A. H., reports on Economic Geology of Illinois, Vols. I, II, III; also Illinois Geol. Survey, Vol. VII.
[c] Illinois Geol. Survey, Vol. III, pp. 37, 101.

A. SHALE PIT NEAR BELLEVILLE, ILL.

B. CRETACEOUS CLAY AT WOODBRIDGE, N. J.

junction of the Kankakee and Iroquois rivers, and extending thence southward to near Chatsworth, in Livingston County, and westward to the Indiana boundary.

The Coal Measure section embraces sixteen seams of coal, No. 1 being the lowest, which are interbedded with a great series of shales, clays, and sandstones. The under clays are often of a refractory character. Owing to the nearly horizontal position of the beds, mining is usually carried on by shaft, although at several localities, as Galesburg and Belleville (Pl. V, *A*), great outcrops of shales occur. The best beds of potter's and fire clays in the State are associated with the lower or No. 1 coal seam. Many excellent sections are given in the reports of the Illinois Geological Survey. Unfortunately little has been published regarding the economic value of the clays and shales of this State, although they form the basis of an active clay-working industry. The Carboniferous shales are employed, however, in the manufacture of paving brick, terra cotta, pressed brick, roofing tile, and other clay products, the results produced being excellent.[a]

Many references are given by Mr. Worthen[b] to individual occurrences of clay in Illinois, among which the following may be specially mentioned:

Beds of fire clay in Illinois.

County.	Occurrence.
Adams	Good fire and pottery clays under coal seams 1 and 2.
Brown	Good potter's clay at Ripley and Lagrange. Fire clay under No. 2 seam.
Clark	Good white clay reported in a shaft near Marshall, 80 to 85 feet below the Livingston limestone.
Fulton	Fire-clay beds 3 to 5 feet thick under cannel coal at Avon; at other localities under lower coal.
Greene	Pottery clay under coal in Wolffs Run.
Grundy	Brick yards at Morris use weathered calcareous shale overlying lower coal. Below this are 35 feet of fire clay and soft shales.[c]
Hancock	Fire clay under lower seam.
Lasalle	Much fire clay under several beds.
St. Clair	Fire clay under two lower coal seams.
Scott	Valuable clay under Exeter seam near Winchester.
Schuyler	Fire clay under No. 2 coal seam, exposed on Sugar Creek. Another bed near Rushville.

[a] Illinois Geol. Survey, Vol. VII, p. 1-38.
[b] Economic Geology of Illinois, Vols. I, II, III.
[c] Idem, Vol. III, p. 404.

TERTIARY CLAYS.

In Pulaski and Alexander counties the Tertiary contains beds of potter's clay, as at Mound City on the Ohio River and near Santa Fe. The clays at both these points are said to have been used for pottery manufacture.

DRIFT CLAYS.[a]

These form an abundant supply of surface material all over the State. Around Chicago these clays are lake deposits of considerable extent, but they are very calcareous and contain many pebbles. They are extensively worked for making common brick and roofing tile. In other portions of the State the clays are found in the drift or underlying terraces along the broader rivers, especially the Illinois. At Fielden, Jersey County, the clay at the base of the drift is used for pottery.[b] Many loess and drift clays occur in Pike, Ripley, Fulton, McHenry, Lake, Morgan, Bureau, Will, Salina, and Rudolph counties.

CLAY-WORKING INDUSTRY.

Illinois is the fourth State in importance as a clay producer, having over 560 clay-working plants. Common brick are manufactured at many places in all parts of the State, Chicago being the most important. Considerable quantities are also made at Bloomington, Danville, Peoria, Quincy, and Streator. Surface clays are commonly employed.

Pressed brick are also an important item of production. Illinois is a large producer of paving brick, factories being located at Utica, Streator, Springfield, Galesburg, Alton, etc. Two roofing-tile works are located in the State, the one at Ottawa using Carboniferous shales, the other, at Chicago Heights, employing calcareous lake clays. Fire brick are manufactured to some extent from the under clays of the coal seams to supply a local demand, but many fire clays are also sent from Ohio. Stoneware and earthenware are produced in considerable quantities, and some white ware is made at Peoria, but the clays used are obtained from other States. Terra cotta is made near Chicago from a mixture of Illinois and Indiana materials.

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[a] See Leverett, F., The Illinois glacial lobe: Mon. U. S. Geol. Survey Vol. XXXVIII.
[b] Economic Geology of Illinois, Vol. II, p. 41.

The value of the clay products made in 1900 and 1901 was as follows:

Value of clay products of Illinois in 1900 and 1901.

	1900.	1901.
Common brick	$3,981,577	$5,188,654
Front brick	240,989	204,980
Paving brick	720,089	899,454
Fancy brick	15,705	13,105
Fire brick	175,259	212,510
Drain tile	734,249	696,588
Sewer pipe	271,035	348,716
Terra cotta		812,015
Fireproofing	76,347	263,276
Other tile	229,729	229,746
Miscellaneous	25,237	28,121
Red earthenware	57,068	6,600
Stoneware	578,405	585,649
C. C. ware White granite Miscellaneous	68,000	83,900
Clays (pipes, terra cotta, firestone ware)	52,872	63,131

Value of clay products of Illinois from 1895 to 1901.

Year.	Value.	Rank.	Proportion of U. S. product.
			Per cent.
1895	$7,619,884	3	11.67
1896	5,398,247	4	9.44
1897	5,398,574	5	8.86
1898	6,866,715	4	9.37
1899	7,259,825	5	7.58
1900	7,708,859	4	8.01
1901	9,642,490	4	8.75

INDIANA.

The geologic map of Indiana shows a series of Paleozoic formations, ranging from the Hudson formation to the Coal Measures (see Pl. IV). Outcrops are scarce, however, owing to the heavy covering of drift, and are to be sought chiefly in the valleys. Of these Paleozoic rocks, the Carboniferous are the only ones of importance to the clay worker, for they contain many beds of shale and clay of considerable

value, while neither the Devonian nor Silurian contains plastic materials that offer promise. The Carboniferous rocks are confined to the southwestern corner of Indiana, and contain the most valuable clay deposits found within the State. The drift covers nearly the entire State, and contains many brick and other clays.

KNOBSTONE OR WAVERLY SHALES.

These are found in the western part of Clark and Scott counties, northwestern Washington, most of Jackson and Brown, western Bartholomew, and most of Morgan and Hendricks counties.

In Jackson County there are important outcrops along the White River southwest of Seymour, and also west of Surprise station. The shale is locally known as soapstone. It also outcrops south of Freetown. The best deposits are at a place called Blue Lick on the south side of the Baltimore and Ohio Southwestern Railroad.

The following is the composition of an average sample of Knobstone shale from "Blue Lick," Jackson County, Ind., suitable for paving brick, sewer pipe, roofing tile, and other vitrified products.

Analysis of Knobstone shale from Blue Lick, Jackson County, Ind.

	Per cent.
SiO_2	59.64
TiO_2	1.05
Al_2O_3	19.14
H_2O	4.36
Fe_2O_3	3.39
FeO	4.20
CaO	0.26
MgO	2.31
K_2O	3.53
Na_2O	0.80
CO_2	0.35
Total	99.03
Quartz	25.57
Feldspathic detritus	6.86
$MgCO_3$	0.67
Clay substance	66.90
Total	100.00

COAL MEASURES.

The Coal Measure clays underlie the surface of the southwestern part of the State, as shown on the map (Pl. IV). From this it is seen that Carboniferous clays

and shales are to be found in the counties of Fountain, Vermilion, Parke, Vigo, Clay, Owen, Sullivan, Greene, Knox, Daviess, Martin, Dubois, Pike, Gibson, Vanderburg, Warrick, Spencer, and Perry.[a] Posey County, in the southwestern corner, is entirely covered by the Upper or Barren Coal Measures, and since little coal is mined there, little is known about the clays. The following section shows the arrangement of the clay deposits in this part of the State:[b]

Typical section of Coal Measure strata and interbedded rocks.

	Feet.	Inches.
1. Soil and surface drift clay	9	0
2. Blue, compact shale	27	0
3. Dark, bituminous shale	3	2
4. Coal	2	7
5. Fire clay	4	4
6. Dark, siliceous shale	18	0
7. Sandstone	6	3
8. Dark, bituminous shale	1	0
9. Coal	4	8
10. Fire clay	3	10

The fire clays 5 and 10 in the section are almost invariably found with the coal seams which they underlie. The dark, bituminous shales 3 and 8 of the above section are usually found on top of most of the seams of coal and are known to the miners as "black slate." The blue and drab shales 2 and 6 "comprise the greater part of the Coal Measure rocks of Indiana and, taken as a whole, are the most valuable clay deposits appearing in the State. They are not closely related to the strata found above and below them and their thickness and composition vary excessively."

The relations of the shales, clays, and coal are such that the three can often be mined by one shaft. Since the accompanying coal seams are often referred to, it may be well to state that 14 seams are recognized in the Indiana Coal Measures and are lettered from A to N.

For detailed information the report above referred to should be consulted. The more important occurrences are mentioned below.

Clay County.—This is probably the most important clay-producing county in the State, Brazil, the county seat, being an important clay-manufacturing center. This development dates largely from 1890, and the clays now used supply several branches of the industry.

[a] Platchley, W. S., Preliminary report on the clays and clay industries of the coal-bearing counties of Indiana: Twentieth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 42.

[b] Ibid., p. 43.

A section at the sewer-pipe works, 1 mile northwest of Brazil, in SE. ¼ sec. 25, T. 13 N., R. 7 W., shows the following beds:

Section near Brazil, Clay County, Ind.

	Feet.	Inches.
1. Soil and yellow surface clay	12	0
2. Blue drift clay ("hard pan")	7	0
3. Gray argillaceous shale	33	0
4. Coal K (top or "rider" vein)	2	3
5. Fire clay (potter's clay)	3	2
6. Blue argillaceous shale	19	0
7. Dark fissile shale	1	6
8. Coal, main block "I"	3	6
9. Fire clay	5	4

The fire clay 9 is said to make a strong, durable sewer pipe. The potter's clay beneath the coal K has been used since 1859 in the pottery at Brazil, and the gray shale 3 is utilized by the Indiana Paving Brick Company, the bed being 30 feet thick. The Chicago Sewer Pipe Company, 1 mile southwest of Brazil, makes sewer pipe from the clay shale 3. This is found at present on all sides of Brazil to a distance of 2 miles, except to the southeast, where it seems to be largely replaced by the sandstone. The blue shale 6 overlies the middle vein of the block coal I wherever the latter is found. One mile northwest of Clay City the under clay of the main block coal is mined and shipped for use in the manufacture of ornamental brick, fire brick, and terra cotta. It is similar to the under clay found at the same horizon at Brazil, but not so refractory as the clays at Montezuma. A stoneware pottery has been in operation at Clay City since 1846.

Dubois County.[a]—The most important clay deposits of Dubois County are in the vicinity of Jasper and Huntingburg, where there are outcrops of soft, light-gray shales. There are three veins of coal here, under each of which is fire clay 3 to 5 feet thick and good for pottery or fire brick. A potter's clay is obtained here which is used at Huntingburg and Evansville.[b] A section at the mines of the Huntingburg Pressed Brick Company in Beelers Hill is as follows:

Section at Beelers Hill, Dubois County, Ind.

	Feet.	Inches.
1. Surface and yellow clay	14	0
2. Blue argillaceous shale	16	0
3. Dark bituminous shale	2	0
4. Coal		11–14
5. Potter's clay (choice)	5	10
6. Fire clay impregnated with small grains of iron ore	2	0
7. Soft, gray argillaceous shale	7	0

No. 5 has been shipped and brings 85 cents a ton f. o. b.

[a] Twentieth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 106.
[b] Analysis given in table.

Greene County.[a]—Beds of shale of commercial value are rarely found above coal A, which outcrops in the eastern half of the county, but the fire clay under it is often of excellent quality.

Knox County.[b]—The Upper or Barren Coal Measures form the surface rocks of most of the county, the Lower or Productive Measures outcropping only on the eastern border, especially in the bluffs of White River. The clays have been but little used, although several beds of fire clay occur under coal seams L, K, and M.

Owen County.[c]—The more valuable deposits of clay and shales are found in Ts. 9 and 10 N., and Rs. 5 and 6 W., in which region also are located the upper coal veins. The fire clay is again found under block coal I. The deposit of shale over the coal is one of the best in the State. It belongs to the same horizon and is similar to that worked at Brazil for sewer pipe and other products. The fire clay under the coal is inferior because it contains much pyrites. The fire clay is also found in the mines north of Patricksburg and southwest of the same town. The shale overlying coal I comes to the surface at many places.

Near the town of Freedom, in Owen County, there is a large deposit of pinkish and red clay lying near the surface. It underlies a considerable area and has been shipped to the Encaustic Tile and Terra Cotta Company works at Indianapolis, the Encaustic Tile Works at Anderson, Ind., and to Newark, N. J. It is one of the most important clays of Indiana. Although appearing to be a surface clay it really is a decomposed shale, and when mixed with the less refractory clay from Carbon, Ind., makes a red floor tile.

Perry County.—Potter's and fire clays are exposed in the shaft at the coal mines one-half mile above Troy. Sewer pipes are made from a shale obtained near Cannelton, and the same material is also found to be suitable for the manufacture of stoneware, supplying one of the largest factories of its kind in Indiana. The clay used at both factories is the under clay of the top coal found extensively in the vicinity of Cannelton. The following section is seen on the land of the American Cannel Coal Company, 1¼ miles east of Cannelton:

Section near Cannelton, Perry County, Ind.

	Feet.
1. Soil and yellow clay	6
2. Gray arenaceous shale	14
3. Sandstone	8
4. Blue arenaceous shale	11
5. Coal (top vein)	1– 1½
6. Potter's clay	4–6
7. Blue argillaceous shale	34
8. Black bituminous shale	1½
9. Coal (main vein)	4
10. Fire clay	5
11. Sandstone	20

[a] Twentieth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 87.
[b] Ibid., p. 94.
[c] Ibid., p. 85.

Fire clay 10 burns to a buff color and is not highly refractory. Large quantities of both 7 and 10 in the section have to be handled each year in the mining of the coal, and at present are not being used.

Pike County.[a]—Fire clays are found in the sections under the coal at Sand Hill, 2 miles north of Petersburg; also at Blackburn and again at Plainfield.

Gibson County.[b]—Large deposits of shale occur near Princeton.

Sullivan County.[c]—Fire clays underlie the coal, but only one deposit of pottery clay is known, and that is near Pleasantville.

Vanderburg County.[d]—There are several large clay works at Evansville, among them the Evansville Pressed Brick Company, which uses shales. Fire clay occurs in this county beneath coal N, and is of much better quality than that below vein M.

At the Pressed Brick Company's works, the shale section on Pigeon Creek shows the following beds:

Section on Pigeon Creek, Vanderburg County, Ind.

	Feet.
Surface and yellow clay	5
Drab argillaceous shale	14
Blue arenaceous shale	5
Sandstone	?

This shale, which is both drab and blue, is said to cover a large area north and northwest of Evansville, and outcrops in a number of places along Pigeon Creek and its tributaries.[e]

The shale outcrops are also used near Babytown, in this county, for brick manufacture.

Vermilion County[f]—The entire area of this county is included in the Coal Measure formations, but about one-third is taken up by the terraces and lowland bottoms of the Wabash and its tributaries. The remainder is upland, along the eastern border of which are high bluffs rising above the level of the river. Along these bluffs large and available deposits of under clays and shales are exposed. They are used near Clinton by a brick and pipe company, and also for paving brick, but some of these shales require the admixture of drift clay to the extent of about 25 per cent to prevent warping and cracking in burning. There are many outcrops of shale farther north, between Clinton and Hillsdale, and also north of the latter place. The following rather complete section is found in a ravine in the SW. ¼ sec. 26, T. 16 N., R. 9 W., a short distance from West Montezuma station:

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[a] Twentieth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 110.
[b] Ibid., p. 114.
[c] Ibid., p. 98.
[d] Ibid., p. 110.
[e] Ibid., p. 117.
[f] Ibid., p. 65.

Section near West Montezuma, Vermilion County, Ind.

	Feet.	Inches.
1. Silt and drift	5– 7	0
2. Sandstone	2–10	0
3. Gray arenaceous shale	1– 6	0
4. Coal	3– 5	6
5. Fire clay	3– 4	0
6. Blue or drab argillaceous shale	25–30	0
7. Concretionary iron carbonate (2 bands)		6
8. Black fissile shale	2– 3	0
9. Coal	1	0
10. Fire clay (white siliceous)	5– 7	0
11. Blue and drab argillaceous shale	42	0
12. Black fissile shale	2	0
13. Coal	1	8
14. Fire clay	8	0

Fire clay 10 of the section is the most refractory under clay that has been found in the State, the bricks made from it being sent to Georgia and Alabama. Many good clay outcrops are found west of Newport along the Little Vermilion River. The largest pressed-brick plant in the State is located 1½ miles southwest of Cayuga, in this county, and utilizes the shales outcropping northwest of Newport.[a]

Vigo County.—The largest and most valuable shale and clay deposits are found on the west side of the Wabash River and north of the old National road. The following section is given from Broadhurst's mine, 1 mile west of Maxville, and can be taken as illustrative of the general section in this county:

Section near Maxville, Vigo County, Ind.

	Feet.	Inches.
1. Soil and drift clay	13	0
2. Fossiliferous limestone	2	0
3. Gray argillaceous shale	12	0
4. Sandstone, massive	12	0
5. Shaly sandstone, merging into blue shale or "soapstone"	42	6
6. Coal	4	8
7. Fire clay (not passed through)	6	0

Near Terre Haute a brick and pipe company is working a shale for hollow brick, which is similar to 5 of the above section.

Warrick County.—Coal seams and the accompanying clay and shale beds are known to occur in the county, but on account of lack of railway facilities they have been little developed.

[a] Twentieth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 70.

SHALES AND CLAYS FOR VITRIFIED BRICKS.[a]

The best deposits of unworked shales and clays for making vitrified bricks lie just east of Mecca, Parke County; west of Montezuma, Parke County; west of Terre Haute and near Riley, Vigo County.

Other large deposits of shale of good quality are located 1 mile southeast of Veedersburg; on Cold Creek; on Brouillets Creek; south of Clinton, Vermilion County; section 6, Pierson Township, Vigo County; near Patricksburg and Woodside, Owen County; and near Farnsworth, Sullivan County.

In the tables given below there will be found a number of analyses of Carboniferous shales and clays of Indiana.

Analyses of under clays of Indiana Coal Measures.

	1.	2.	3.	4.	5.	6.
SiO_2	69.23	57.57	54.46	63.00	83.44	68.13
TiO_2	1.50	1.10	1.20	1.10	1.29	.....
Al_2O_3	18.97	21.70	25.71	23.57	10.36	20.80
Combined H_2O	5.46	6.78	8.50	6.45	3.15	5.72
Fe_2O_3	1.57	2.26	5.51	1.87	0.27	1.20
FeO	0.55	4.11	0.91	0.46	0.28	.....
CaO	0.12	0.32	0.24	0.44	0.36	0.42
MgO	0.36	1.12	0.83	0.89	0.14	0.37
K_2O	2.27	2.16	2.68	2.40	0.03	2.28
Na_2O	0.33	0.33	0.33	0.29	0.71	0.27
CO_2	.....	1.73	.....	.....	.....	.....
Total	100.36	99.18	100.37	100.47	100.03	99.19
Quartz	39.36	27.95	19.69	26.31	46.33	.....
Feldspathic detritus	1.67	1.95	0.83	1.00	39.28	.....
$FeCO_3$	.....	3.65	.....	.....	.....	.....
Clay substance	58.37	66.81	79.48	72.69	14.39	.....

1. Under clay No. 5, from mine owned by Bockting Bros., Huntingburg, Dubois County. Used for stoneware at Huntingburg and Evansville.

2. Under clay from beneath the vein of coal worked by the American Cannel Coal Company, Cannelton, Perry County.

3. Under clay No. 8, from the land of S. L. McCune, Mecca, Parke County.

4. Under clay 16, from the land of S. L. McCune, Mecca, Parke County.

5. Under clay No. 10, from the land of Joseph Burns, West Montezuma, Vermilion County. Used for fire bricks.

6. Average of stoneware clays selected from the ground clays used in several of the large Akron, Ohio, stoneware factories, and then mixed. (Inserted for comparison.)

[a] Twenty-fourth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 31.

Analyses of Carboniferous shales of Indiana.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
SiO_2	56.62	59.55	61.46	65.87	65.78	55.09	59.77	59.02	58.83
TiO_2	.....	1.00	1.20	1.10	1.00	1.20	.80	1.10	.70
Al_2O_3	21.63	16.21	16.54	14.66	14.79	20.76	20.60	20.93	22.34
(Combined) H_2O	6.53	5.62	5.09	4.59	4.98	7.01	4.53	7.59	5.22
Fe_2O_3	7.08	2.18	3.77	6.23	8.03	3.00	2.22	4.45	5.13
FeO	.....	7.13	3.71	1.37	.....	4.01	3.70	1.56	1.44
CaO	1.11	.75	.66	.39	.54	1.51	.64	.51	.49
MgO	1.41	1.58	1.81	1.54	1.42	1.18	1.98	1.66	1.56
K_2O	3.14	2.81	3.28	2.66	2.82	2.36	3.10	2.92	4.18
Na_2O	.48	.28	1.09	1.31	.97	.34	.85	.41	.63
CO_2	.....	3.15	1.45	.....	.26	3.04	.90	.....	.....
Total	98.00	100.26	100.06	99.72	100.59	99.50	99.09	100.15	100.52
Quartz	.....	34.61	27.94	36.87	34.34	20.90	26.04	23.82	22.81
Feldspathic detritus	.....	1.81	8.56	13.07	12.58	2.03	8.37	3.28	8.30
Ferrous carbonate	.....	8.61	3.82	.....	.....	6.46	2.37	.....	.....
$MgCO_3$	.....	.....	.....	.....	.50	1.13	.....	.....	.....
Clay substance	.....	54.97	59.68	50.06	52.58	69.48	63.22	72.90	68.89

	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
SiO_2	61.05	56.68	53.26	64.05	46.07	56.32	55.31	62.04	67.82	68.46
TiO_2	1.20	.90	1.05	1.00	1.19	1.07	1.15	1.30	1.10	1.49
Al_2O_3	21.46	20.33	25.77	16.00	24.22	24.34	22.46	18.49	13.60	16.08
(Combined) H_2O	6.94	6.54	7.00	3.79	9.76	6.33	7.48	6.50	9.72	7.04
Fe_2O_3	5.57	4.35	3.32	.89	9.65	5.60	7.18	7.54	4.04	1.92
FeO	.71	3.69	3.82	5.85	.34	.24	.23	.06	.45	.06
CaO	.25	.57	.32	.42	.19	.31	.66	.16	.57	.99
MgO	.70	2.04	1.90	2.00	1.31	.54	.93	.91	.44	.05
K_2O	2.34	3.15	2.54	2.59	1.66	2.85	2.05	.93	1.68	1.31
Na_2O	.30	.63	.44	1.19	2.76	2.34	2.06	2.04	1.18	2.40
CO_2	.....	.47	1.10	2.68	2.87	.....	1.24	.....	.....	.....
Total	100.52	99.35	100.52	100.46	100.02	99.94	100.75	99.97	100.60	99.80
Quartz	25.87	29.85	28.66	.....	15.91	13.19	11.91	30.60	38.70	37.58
Feldspathic detritus	1.62	8.24	2.32	.....	13.39	13.21	25.38	16.68	17.90	16.87
Ferrous carbonate	.....	1.23	2.90	.....	.54	.....	.37	.....	.....	.....
$MgCO_3$	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Clay substance	72.51	60.68	66.12	.....	70.72	73.54	63.46	52.69	44.00	45.35

1. Average of ten analyses of shales used in the manufacture of paving brick and sewer pipe in the State of Ohio. Adopted as the standard for this report. (Inserted for comparison.)

2. Mixture of shales and surface clay as used by the Wabash Clay Company, Veedersburg, Fountain County, in the making of paving blocks.

3. Mixture of shales and small amount of surface clay as used by the Clinton Paving Brick Company, Clinton, Vermilion County, for the making of paving brick. Average sample.

4. Mixtures of shales and surface clay as used by the Evansville Pressed Brick Company, Evansville, Vanderburg County, in the making of paving and dry-pressed brick. Average sample.

5. Mixture of shales 3 and 4, from the clay pit of the Cayuga Pressed Brick Company, Vermilion County. Used for making red dry-pressed brick. Average sample.

6. Bastard shale 5, from the pit of the Cayuga Pressed Brick Company, Vermilion County. Used in the making of buff dry-pressed brick. Average sample.

7. Shale 2, from the land of S. L. McCune, Mecca, Parke County.

8. Shale 9, from the land of S. L. McCune, Mecca, Parke County.

9. Shale 5, from the land of S. L. McCune, Mecca, Parke County.

10. Shale from the land of H. T. Thorp, near Terre Haute, Vigo County.

11. Mixture of shales from railway cut near Lincoln City, Spencer County.

12. Shale 7, from above the main vein of coal worked by the American Cannel Coal Company, Cannelton, Perry County.

13. Shale from above the worked vein of coal, Prospect Hill mine, Vincennes, Knox County.

14. Shale 6, from the land of Joseph Burns, West Montezuma, Vermilion County.

15. Shale 11, from the land of Joseph Burns, West Montezuma, Vermilion County.

16. Shale 8, from above the worked vein of coal, shaft No. 1, Island Coal Company, Linton, Greene County.

17. Shale from near "Air-line" shops, Princeton, Gibson County.

18. Shale from the land of Frank Landers, near Stonebluff, Fountain County.

19. Shale from the land of J. W. Shuster, near Stonebluff, Fountain County.

KAOLIN.

At several localities in Lawrence, Martin, and Owen counties are found deposits of white clay known as indianaite, the best-known occurrence being near Huron, Lawrence County.

These deposits were first mentioned by E. T. Cox, in the report for 1874, and the kaolin was locally known as mineral tallow. It was at one time used at Cincinnati for making white ware, and later it was used by the Pennsylvania Salt Company. It varies from 4 to 11 feet in thickness, with an average of 5½ to 6 feet, forming a horizontal stratum overlain by sandstone, and in places contains a light green mineral known as allophane. The upper half of the kaolin stratum is chiefly composed of massive snow-white clay, associated with which, near its upper part, are occasional concretionary masses, some of them a foot or more in diameter. They disintegrate on exposure to air, but the kaolin is nonplastic. The lower half of the kaolin ranges from pale buff to rich, deep brown in color. An analysis of this kaolin is as follows:

Composition of indianaite.

	Per cent.
Silica	44.75
Alumina	38.69
Water	15.17
Ferric oxide	.95
Lime	.37
Magnesia	.30
Potash	.12
Soda	.23
Total	100.58

Kaolin outcrops at several places in the eastern half of Martin County, and beds have been worked on small scale.[a] One mine is on the south side of White River in NW. ¼ sec. 27, T. 3 N., R. 4 W., 2½ miles west of Shoals. Here the kaolin is 4½ to 5 feet thick, but is not uniform in character. The uppermost layer is a hard, semi-transparent, milk-colored clay. Under this is a soft, chalk-white to cream-colored clay. The third layer is hard, dark amber brown to black, with much iron oxide. Kaolin is also found near Willow Valley and Pleasant Valley. A number of outcrops are seen north of White River, one of these being near the town of Dover Hill. Another deposit is three-fourths of a mile south of the Indiana Springs Hotel. The kaolin is considered to underlie the greater part of the eastern half of Martin County, at the lower horizon of the Conglomerate sandstone of the Carboniferous.

In Owen County[b] kaolin is known to occur 5 miles southeast of Spencer. It probably underlies the greater part of T. 9 N., R. 3 W.

In Greene County[c] kaolin similar to that found in Lawrence and Martin counties is found in Beech Creek Township and near Newark.

PLEISTOCENE CLAYS.

These are soft, plastic clays, found at the surface or at no great distance below it, and while occurring over a large part of the State, they are especially important in the northwestern part of Indiana, and on this account have been made the subject of a special report.[d]

In this region three classes are distinguishable, viz, drift clays or "hard pans," alluvial clays, and silty or marly clays.

The drift clays are the most common type, forming a large percentage of the unstratified morainic material, but they are usually too impure for making anything but common brick and tile. They are often calcareous.

[a] Twentieth Annual Rept. Ind. Dept. Geol. and Nat. Res., 1895, p. 101.
[b] Ibid., p. 86.
[c] Ibid., p. 88.
[d] Blatchley, W. S., The clays of northwestern Indiana: Twenty-second Ann. Rept. Ind. Dept. Geol. and Nat. Res., 1897.

The alluvial clays form larger deposits along the lowlands and second bottoms of the larger streams of northwestern Indiana. They have been formed during periods of overflow, and in some places show a thickness of 30 to 90 feet. They are free from pebbles or coarse particles, and usually possess high plasticity.

The silty or marly clay resembles the preceding class very closely, but differs in having been deposited in bays, lakes, or harbors in quiet water. These clays are usually finer grained than the alluvial ones, are thinly laminated, and often highly calcareous, so that they produce a buff product. The occurrence of these clays in Benton, Newton, Jasper, Starke, Lake, Porter, Laporte, and St. Joseph counties has been discussed in a report of the Indiana geological survey.[a] Their general character can be judged from the facts given below.

Benton County.—This county lies on the western border of the State, and the clays found in it are all of glacial origin, many of them lying immediately under the black prairie loam. Their thickness ranges from 5 to 20 feet, and the best deposit, which is at Earl Park has been worked since 1891. Its section is as follows:

Section at Earl Park, Benton County, Ind.

	Feet.
1. Soil stripping	8
2. Coarse-grained yellow clay with small pebbles	4
3. Fine-grained drab clay	8
4. Blue clay, marly, fine grained	38
5. Limestone.	

2 has little lime; 3 and 4 are similar, often contain pebbles, and are calcareous. At Lochiel the clay resembles the upper stratum of the Earl Park section and is used for making hollow brick. Drain tile and ordinary brick are made from the drift clays at Fowler, and tile factories are located at other places in the county.

Newton County.—Much of the surface of this county is covered with loose sand, and the clays are all drift or marly ones, being either deposits from the melting ice or laid down just after the close of the Glacial epoch. In places their thickness is 120 to 140 feet, but in others it is less than 10 feet. A sand cover in the northern part of the county conceals much of the clay. The most extensive workings are around Brook, where the following section was taken:

Section at Brook, Newton County, Ind.

	Feet.
Black soil	1
Yellowish, loamy clay	2
Gray or drab marly clay	3–6
Tough-blue marly clay	2–5
Gravel and sand.	

[a] The clays and clay industries of northwestern Indiana, Twenty-second Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 112.

The clay is used in the manufacture of terra-cotta lumber and hollow brick.

Jasper County.—Clays occur at several points, the best being 1½ miles north of Rensselaer, where the deposits are 13 to 15 feet thick.

Starke County.—There is much marshy land in this county which has been drained, and at other places there are sandy and prairie soils; but beneath these throughout northwestern Indiana there is a vein of fine-grained ash-blue bowlder clay. At times this appears at the surface.

Lake County.—Two kinds of clays are found in this county, viz, the drift clays and the silty or marly clays. The former are used at Lowell and Crown Point for brick and tile, the latter on large scale at Hobart for terra-cotta lumber, flue lining, fireproofing, and common and pressed brick. The pit at Owen, north of Hobart, has an area of 4 acres and is 25 feet deep, showing the following section:

Section at Owen, Lake County, Ind.

	Feet.	Inches.
1. Soil		6
2. Fine-grained, yellowish marly clay	2½–3	0
3. Bluish gray clay, very fine grained	21	0

These clays are evidently lacustrine deposits formed during the highest stage of the glacial Lake Chicago.[a]

Porter County.—Here again the drift clays and the marly ones occur. The former are used for common brick and common tile at Hebron and Valparaiso. The marly clays are used in the manufacture of pressed-brick at Porter and of common brick at Granite City and Chester.[b] At the junction of the Michigan Central and Lake Shore railroads at Porter, Ind., is the largest pressed-brick factory in the State, operated by the Chicago Hydraulic Pressed Brick Company. The clay underlies an area of 45 acres to a depth of 6 feet.

Laporte County.—This includes Michigan City, northeast of which, along Treaty Creek, are large deposits of bluish-gray marly clay.[c]

St. Joseph County.—The best deposits are in the immediate vicinity of South Bend, and along the St. Joseph River, consisting of thick beds of pearl-gray marly clay which is very fine-grained and plastic. Bluish clay here is in places 50 feet thick.

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[a] Twenty-second Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 33.
[b] See table of analyses below.
[c] Analysis No. 4 of following table.

The following analyses indicate the character of these surface clays:

Analyses of clays of northwestern Indiana.

	1.	2.	3.	4.
SiO_2	50.56	50.37	53.02	50.47
TiO_2	1.00	.65	1.30	1.45
Al_2O_3	13.11	9.93	10.72	12.77
Combined water	2.76	1.50	2.21	3.14
Fe_2O_3	2.98	2.10	2.54	2.44
FeO	2.34	2.05	2.22	2.52
CaO	7.87	10.26	8.38	8.17
MgO	5.06	6.26	5.28	5.22
K_2O	3.74	3.04	3.25	3.70
Na_2O	0.70	0.79	0 86	0.73
CO_2	9.62	12.50	10.48	9.80
Total	99.72	99.45	100.26	100.41
Quartz	23.61	28.78	24.89	21.39
Feldspathic detritus	15.94	11.14	14.91	12.70
$CaCO_3$	14.05	18.32	14.86	14.59
$MgCO_3$	6.54	8.48	7.60	6.42
Clay substance	39.86	33.28	37.74	44.90

1. Average of the material used in making terra-cotta lumber at Hobart, Lake County, Ind.

2. Average sample of the upper portion of the bed of bluish-gray marly clay at Garden City, Porter County, Ind.

3. Average sample of the bluish-gray marly clay from the pit of P. E. Anderson & Sons, Chesterton, Porter County, Ind.

4. Average sample of the bluish-gray marly clay from the pit of Roeske Bros., Michigan City, Laporte County, Ind.

Miscellaneous occurrences.—Prof. W. S. Blatchley, State geologist of Indiana, informed the writer that the majority of the surface clays of the northern portion of the State are similar to those that occur around South Bend. The following analysis is somewhat typical of the drift clays of northern Indiana:[a]

Analysis of drift clay 2 miles northwest of Turkey Lake, Lagrange County, Ind.

	Per cent.
Silica	56.74
Alumina	19.43
Ferric oxide	4.83
Lime	7.27
Magnesia	3.05
Loss on ignition	10.39
Total	101.71

[a] Twenty-fifth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 112.

The section of the deposit is as follows:

Section of drift-clay deposits 2 miles northwest of Turkey Lake, Lagrange County, Ind.

	Feet.
Sand	1½
Clay	6
Clay with pebbles	3+

At Coal City, in Owen County, is one of the largest ordinary brickyards in western Indiana.[a] The clay used is a yellow surface clay, free from lime.

A yellow surface clay near Huntingburg makes a fine red-front brick and closely resembles that worked at Washington, Ind.[b]

A surface clay occurs near Princeton, resembling those so characteristic of the southern counties of Indiana. Fine pressed brick are made from it at Huntingburg, Dubois County. It burns to a good red color. Its analysis is as follows:[c]

Analysis of surface clay near Princeton, Gibson County, Ind.

	Per cent.
Silica	71.20
Titanic acid	.88
Alumina	18.56
Ferric oxide	1.34
Ferrous oxide	.15
Lime	.14
Magnesia	.52
Potash	.32
Soda	1.26
Water	6.30

Many deposits of good surface clays also occur in the vicinity of Gosport, Owen County. They are abundant in Spencer County, around Rockport.[d]

At Switz, drift clay is found 3 feet below the surface; and also a thick stratum of tough, blue drift clay, making excellent drain tile.[e]

In the vicinity of Washington, Daviess County, there is found a good grade of yellow surface clay, averaging 15 to 18 feet in thickness, which can be made into a fine, dry-pressed, front brick. Fire clays for mixing with it are obtainable not far off.

The river bottoms of Vigo County are bordered by river terraces which vary in width from 3 to 8 miles and contain considerable quantities of recent sedimentary clays. A good grade of dry-pressed brick is made from a bed of such clay over 20 feet thick found in the lowlands of the Wabash River, near Terre Haute, in this

[a] Twentieth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 85.
[b] Ibid., p. 109.
[c] Ibid., p. 114.
[d] Ibid., p. 121.
[e] Ibid., p. 88.

county. The clay is of even texture and free from pebbles, but an objection to it is the lack of uniformity in the shade of the burned clay.

The following is an analysis of the Terre Haute sedimentary clay:

Analysis of Terre Haute sedimentary clay.

	Per cent.
Silica	66.11
Alumina	13.78
Water	6.34
Ferric oxide	5.35
Lime	1.67
Magnesia	1.78
Potash	2.11
Soda	1.15
Total	98.29

Drift clays are said to occur over most of Miami County.[a] They occur either at the surface or interbedded with sand and gravel. Pottery clays are known at Denver. In Allen County brick and tile clays are common in the surface formations,[b] and the same is true of Marshall County.[c]

CLAY-WORKING INDUSTRY.

Indiana ranks seventh among the clay-producing States. This is due partly to the presence of many clays well suited to the manufacture of brick and other clay products, and also the proximity of several large cities, such as Indianapolis and Chicago.

The value of the clay products of Indiana is shown by the following figures.

Value of clay products in Indiana from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$3,117,520	6	4.77
1896	2,674,325	7	4.30
1897	2,712,309	6	4.62
1898	3,331,997	6	4.49
1899	4,235,354	6	4.42
1900	3,858,350	6	4.01
1901	4,466,454	7	4.05

[a] Sixteenth Ann. Rept. Ind. Dept. Geol and Nat. Res., p. 176.
[b] Ibid, p. 127.
[c] Fifteenth Ann. Rept. Ind. Dept. Geol. and Nat. Res., p. 180.

Value of clay products of Indiana in 1900 and 1901.

	1900.	1901.
Common brick	$1,391,873	$1,624,133
Front brick	172,752	234,775
Vitrified brick	331,276	320,221
Fancy or ornamental	7,310	8,160
Fire brick	40,976	51,526
Stove linings	(a)	(a)
Drain tile	674,602	772,241
Sewer pipe	279,719	253,626
Ornamental terra cotta	(a)	(a)
Fireproofing	116,581	91,081
Tile	343,985	478,130
Red earthenware	4,337	6,650
Stoneware	44,207	47,712
Other pottery wares	229,830	413,000
Clay mined	21,145	25,705
Miscellaneous	112,576	50,790

a Less than three firms reporting.

Common brick.—Common brick are manufactured at a great many localities, usually from drift clays.

Pressed brick.—Pressed brick are produced at Cayuga, Vermilion County; Hillsboro, Fountain County; Terre Haute, Vigo County; Huntingburg, Dubois County; Evansville, Vanderburg County; and Montezuma, Parke County. They are made in part from semifire clays, but also from alluvial ones. At Porter, Porter County, the drift clays are used.

Paving brick.—Paving brick are manufactured at several places in Indiana, among them Clinton, Vermilion County; Veedersburg, Fountain County; Brazil, Clay County; Evansville, Vanderburg County; and New Albany, Floyd County.

Fireproofing.—This is made in large quantities near Hobart, in northwestern Indiana. The material used is calcareous glacial clay.

Sewer pipe.[a]—The clays used for making these are the same as those employed for paving brick, namely, the under clays and shales. Shale is used at Brazil, but most of the works at other places prefer the under clay. Pumps are made from semi-refractory clay at Brazil, Ind., and sewer pipes are manufactured also at Mecca, Parke County; Cannelton, Perry County; and Terre Haute, Vigo County.

a Twentieth Ann. Rept. Dept. Ind. Geol. and Nat. Res., p. 164.

Fire bricks.—These are made but at four factories in Indiana, which get their clay from the stratum underlying a large area in Parke and Vermilion counties. It is a white semiplastic under clay. The factories are located at Hillsdale and Montezuma.

Pottery.—Both earthenware and stoneware are made by many small works in the coal-bearing counties, there being 11 factories making stoneware, 3 of which are of considerable size. One factory at Evansville makes white graniteware. Stoneware clays are especially mentioned by Blatchley,[a] from the vicinity of Annapolis, Parke County; Brazil, Clay County; Shoals, Martin County; Huntingburg, Dubois County; and Cannelton, Perry County. Stoneware is made at Annapolis, Bloomingdale and Rockville, Parke County; Brazil and Clay City, Clay County; Worthington, Greene County; Shoals, Martin County; Huntingburg, Dubois County; Cannelton, Perry County; and Evansville, Vanderburg County.

KENTUCKY.

No systematic report has ever been issued on the clays and shales of the State, and except as to the Jackson Purchase region the information published is mostly of a scattered character, although many samples, collected from time to time by the geologists of the Kentucky geological survey, have been analyzed and the results are published in the State geological reports.[b]

Within the State there are found a series of geologic formations ranging from the Ordovician to the Pleistocene. Some of these contain deposits of soft, plastic clays or shales, while others yield clays only as a result of surface weathering. A section across the State from east to west shows that the formations are not highly tilted, as they are farther eastward, but that they are rather flat, having a comparatively gentle dip, so that in any one area where two formations are exposed the older of the two may have been laid bare as a result of erosion.

Beginning with the oldest or Ordovician, we find that this occupies an irregularly shaped area in the northern part of the State. The Trenton limestone of this series forms a large portion of the surface in the counties of Jessamine, Woodford, Mercer, Boyle, and portions of Scott, Franklin, Bourbon, and Fayette. Surrounding this is a much larger area where the upper portion of the Ordovician is exposed in the counties of Boone, Kenton, Campbell, Gallatin, Carroll, Grant, Pendleton, Bracken, Mason, Robertson, Harrison, Henry, Wayne, Nichols, Scott, Shelby, Spencer, Anderson, Washington, Garrard, Madison, Clark, Montgomery, and Bath. Outcropping on the eastern and western sides of this area is a strip of Upper Silurian which on the western side passes through the counties of Trimble, Oldham, Jefferson, Bullet, Nelson, and on the eastern side through Lewis, Fleming, and Bath counties.

[a] Twentieth Ann. Rept. Ind. Dept. Geol. and Nat. Res., 1895, p. 171.
[b] See Kentucky Geol. Surv., Chem. Anal., Pts. I, II, III.

Devonian rocks surround the Silurian areas on the east, west, and south, forming a narrow, irregular patch, whose exact distribution can best be seen from an examination of a geologic map of the State. The Lower Carboniferous is found in both the eastern and western half of the State. It forms an irregular band extending southwestward from opposite Portsmouth, Ohio, through Lewis, Rowan, Menifee, Powell, and Rockcastle counties, and then broadening considerably, it is exposed through the central part of the State as far eastward as the western boundary of Howard County. The area then splits, one portion spreading northwestward into Hardin, Breckinridge, and Meade counties, the other fork extending through the southern part of the State in Warren, Logan, Todd, and Christian counties, as far west as the Tennessee River and north to the Ohio. The Upper Carboniferous rocks underlie two large areas of more or less solid outline. One of these areas is in the eastern part of the State and extends from the West Virginia and Virginia borders northwest and west to the Lower Carboniferous boundary. The second area forms a large more or less rectangular patch in the western part of the State, reaching along the Ohio River from Skillman, in Hancock County, to Blackburn, in Union County. South of these points this area extends approximately as far as the northern boundary of Christian, Todd, Logan, and Warren counties. From the southeastern corner of it a branch extends eastward, covering most of Edmonson and Grayson counties. The Tertiary area occupies that portion of the State between the southern boundary and the Tennessee and Ohio rivers. In this area there are some small strips of Cretaceous in Marshall and Calloway counties and some broad patches of Pleistocene along the Ohio River.

LOWER SILURIAN, OR ORDOVICIAN.

The Ordovician rocks may yield two types of plastic material, viz, residual clays and shales.

The residual clays are derived chiefly from the limestones of this formation and form a tough red clay, the dominant soil type of the Blue Grass region. They are probably well adapted to the manufacture of red brick and perhaps earthenware.

The Ordovician shales occur in both the Cincinnati and the Hudson groups, but in most places they are probably calcareous, so that they are better adapted to the manufacture of Portland cement than bricks. Calcareous clay is derived from the upper Hudson shales in Oldham County;[a] from the Cincinnati group, on the Lexington turnpike, 2 miles south of Covington;[b] in Jefferson County:[c] and in Campbell County, one-fourth mile from Newport.[d] Shales obtained from the Cincinnati group near Bridgeport have been used for making paint.[e]

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[a] Kentucky Geol. Survey, Report on Oldham County, p. 19.
[b] Idem, Report on Kenton County, p. 133.
[c] Idem, Report on Jefferson County, p. 50.
[d] Idem, Chem. Anal., Pt. I, 1884, p. 34.
[e] Ibid., p. 76.

The following are analyses of some of these shales:

Analyses of Lower Silurian shales from Kentucky.

	1.	2.	3.	4.	5.
Silica	56.40	43.461	47.16	47.32	47.96
Alumina, Ferric oxide, Manganese dioxide	29.971	21.000	22.85	28.05	21.34 6.60
Lime carbonate	.760	27.040	20.14	13.49	.....
Lime	.....	.....	.....	.....	5.824
Magnesia	1.514	.680	.84	1.135	3.524
Phosphoric acid	.166	.607	.128	3.254	.....
Potash	3.538	2.447	2.301	.64	5.264
Soda	.551	.915	1.590	.345	.250
Ignition	7.100	3.85	5.200	4.80	9.238

1. Clay from Cincinnati group, 2 miles south of Covington. Kentucky Geol. Survey, Chem. Anal., Pt. I, p. 133.

2. Marly shale, Cincinnati group, junction of Ohio and Licking rivers, 12 feet above low-water mark. Ibid., p. 134.

3. Marly shale, between impure limestone, 5 feet above low-water mark, Whitehall. Ibid.

4. Marly shale from Cincinnati group, one-fourth mile from Newport, upper blue clay. Ibid., p. 36.

5. Clay shale from Cincinnati group, Jeffersontown, Jefferson County. Idem, Pt. II, p. 50.

UPPER SILURIAN.

The Upper Silurian rocks yield clays and shales similar to the Ordovician as far as known. Some good clays are said to exist in the lower beds of the series.[a] In Madison County[b] a good quality of clay is mentioned from Waco, 9 miles east of Richmond, while marly shales occur in Henry,[c] Fulton,[d] Campbell, and Franklin counties. In Fleming County[e] the shale of the Niagara group yields a stiff, blue clay. Other clays are found in Madison and Clark counties.[f]

[a] Kentucky Geol. Survey, new series, Vol. III, p. 156.
[b] Idem, Chem. Anal., Pt. I, p. 288.
[c] Ibid., p. 130.
[d] Ibid., p. 83.
[e] Idem, Report on Fleming County, p. 70.
[f] Idem, Report on Clark County, p. 28.

The following analyses indicate the composition of some of these Silurian shales:

Analyses of Upper Silurian shales from Kentucky.

	1.	2.	3.	4.	5.	6.
Silica	42.3	48.78	59.976	56.96	59.000	42.56
Alumina	20.84	17.32			20.68	20.98
Ferric oxid	4.12	3.24	27.64	28.74	4.96	
MnO and P_2O_5						
$CaSO_4$		19.285				
Lime	13.32				1.456	8.680
Lime carbonate			.280	.20		
Magnesia	.461	.496	.606	.752	1.096	7.247
Potash	2.387	4.768	3.931	2.502	5.500	4.819
Soda	.351	.24	.547	.315	.217	.166
Loss on ignition, etc	16.221	5.871	7.02	10.531	8.091	15.548

1 and 2. Analyses of shale of Niagara group from Madison County.

3. Potter's clay, Waco, Ky., first grade. Kentucky Geol. Survey, Chem. Anal., Pt. I, p. 288.

4. Potter's clay, Waco, Ky., second grade. Ibid., p. 288.

5. Shaly clay from land of F. W. Lewis, 2 miles south of Bobtown, in Madison County; sample of upper 10 inches. Ibid., p. 296.

6. Shaly clay from same locality, from 10 to 20 inches below the surface. Ibid.

DEVONIAN.

Little is known regarding the value of the Devonian for clay working. As stated above, it occupies a rather limited area.

The following analysis is given of the "Ohio" shale:[a]

Analysis of Ohio shale from Kentucky.

	Per cent.
Silica	63.12
Alumina and ferric oxide	8.56
Lime	6.261
Magnesia	2.034
Phosphoric acid	.143
Potash	1.363
Ignition	12.00
Total	93.481

An excellent grade of pottery is made at Waco from the residual clay of the Panola shale.

[a] Kentucky Geol. Survey, Chem. Anal., A, Pt. I, 1884, p. 150.

LOWER CARBONIFEROUS.

The Lower Carboniferous contains several deposits of shales and clay, whose character must be mostly judged from the chemical analyses given below. In Montgomery County the Lower Carboniferous shales yield heavy clays.[a]

Analyses of Lower Carboniferous clays and shales.

	1.	2.	3.	4.	5.	6.	7.	8.
Silica	66.96	80.16	77.66	74.46	71.56	67.56	49.689	61.10
Alumina	15.626	11.60	16.80	20.44	22.86	22.54	19.026	18.20
Ferric oxid	8.38						3.932	6.00
Lime	0.493	[a].76	.48	.64	.68	.98	.927	4.904
Magnesia	.677	.56	Undet.	Undet.	Undet.	.671	1.96	1.542
Phosphoric acid	.154	Undet.	...do ..	...do ..	...do ..	.025	.....	.....
Potash	3.295	3.854	1.002	...do ..	...do ..	2.47	3.827	4.101
Soda	.628	.583	.484	...do ..	...do ..	.058	.288	.821
Ignition	3.787	2.483	4.34	4.46	4.90	5.696	17.41	3.332

[a] Carbonate.

1. Marly clay shale, Tar Creek Hill, near Cloverport, Breckinridge County. Kentucky Geological Survey, Chem. Anal., Pt. I, p. 374.

2. Siliceous clay, Souder's farm, near Green River, Chester group; 4 to 6 feet thick. Ibid., p. 242.

3. Same farm, on Caney Branch, 1 mile from Green River, 7 to 8 feet thick. Upper layer. Ibid.

4. Same, second layer.

5. Same, third layer.

6. Same, lowest layer.

Last four (3, 4, 5, 6), suggested for common pottery.

7. Plastic clay, Waverly group, land of G. Glasgow, 3 miles south of Berea, Madison County. Idem, Pt. II, p. 297.

9. Marly clay, Keokuk group, Nelson County. Recommended for terra cotta. Ibid., p. 67.

UPPER CARBONIFEROUS, OR COAL MEASURES.

The Upper Carboniferous of Kentucky occupies, as already stated, two distinct areas, one in the eastern part of the State, the other in the western.

CLAYS OF EASTERN COAL FIELD.

The eastern area covers about 11,000 square miles, and is a continuation of the Ohio, West Virginia, and Virginia areas. Attempts to correlate the Kentucky seams, however, with those of the States mentioned, have met with difficulty, and it is not always possible; indeed, the sections at opposite ends of the Kentucky area are hard to correlate.

[a] Eng. and Min. Jour., Vol. LXVI, p. 190.

The following comparative sections are given by MacFarland:[a]

Section showing correlative beds in Kentucky, Ohio, and Pennsylvania.

Kentucky.	Ohio.	Pennsylvania.
Coal No. 1	Jackson Shaft	Sharon.
Coal No. 3	No. 3	Lower or Upper Mercer.
Elkhorn		
Jellico		
Peach Orchard		
Coal No. 4	No. 4	
Coal No. 5	No. 6	Brookville.
Coal No. 7	Sheridan	
Ashland	Hocking No. 10	
Coal No. 8	No. 11	Lower Kittanning.

The general section given for Greenup, Boyd, Carter, and part of Lawrence counties,[b] shows a bed of fine clay near the base of the subconglomerate, and a second one under coal No. 6.

That in the subconglomerate bed is a fire clay.[c] Like the coal with which it is often closely associated, it may sometimes be entirely wanting, as at points where the conglomerate sandstone follows the limestone without an intervening bed of shales of considerable thickness. This fire clay is said to correspond to that used at Scioto-ville, Ohio, and is of good quality and inexhaustible quantity. Following is an analysis of average sample from the upper part of the bed at Boone Furnace:

Analysis of fire clay from Boone Furnace, Ky.

	Per cent.
Silica	48.56
Alumina	37.471
Iron oxide	trace
Lime	.112
Magnesia	trace
Phosphoric acid	.255
Potash	.289
Soda	.283
Ignition	13.03
Total	100

Other analyses show more silica. The bed is from 4 to 6 feet thick. On Mr. Ratcliffe's place, near the lime kilns, it shows a thickness of 8 feet, but is not all of good quality.

[a] Trans. Am. Inst. Min. Eng., Vol. XXV, p. 520.
[b] Kentucky Geol. Survey, Eastern coal field, Pl. I.
[c] Ibid., section 2, Pl. XXIX, and section 28, Pl. VIII.

The bed occurs in nearly all of that portion of Greenup and Carter counties which presents the rocks of this horizon above drainage.[a] It has also been noted further southward along the western outcrops of the Coal Measures, and has been mined and shipped in large quantities to Cincinnati from the head of Indian Run, in Greenup County.

In the valley of Schultz Creek and on Plumb Creek, at the place of Judge Fullerton,[b] the section shows shale underlying the block iron ore and overlying the Conglomerate sandstone. Fire clay is wanting on the south side of the valley, where the Conglomerate sandstone has great development, but on the opposite side the conglomerate is not so prominent and fire clay is said to be present. The fire clay would probably be found all along the ridge. An interesting section is seen at Thomson's bank,[c] where the coal is underlain by 20 feet of shales, including fire clay.

West of Boone Furnace,[d] at the old orchard drift on Overmans Creek,[e] the section shows a bed of nonplastic fire clay underlying the double coal seam.[f] The subconglomerate shales are also present, as is shown by the occurrence of the fire-clay bed exposed above forks of the creek on the middle branch, where there are 6 feet of nonplastic clay of fine quality. The general section in this region, known as the Stewart section, is given below[f].

General section of Coal Measures in Rockcastle County, Ky.

	Feet.
Clay shales	
Stewart ore slope	65
Block ore slope	165
Thin coal slope (shales)	45
Conglomerate sandstone	30
Nonplastic fire clay	6
Covered (shales)	15
Limestone	

The sections given in the report referred to above[g] indicate the presence of fire clay at several points. Thus under coal 2 it is seen at the McHenry coal property, at Beach Orchard, and under Bogg's coal, all in Lawrence County. On Irish Creek shale underlies the coal. Fire clay is shown under coal 3, at Raccoon Furnace, Pennsylvania Furnace and Bellefont Furnace, Hunnewell Furnace, head of Dry Fork, and also in the Holbrook Bank, Brushy Creek.[h] Under coal 4 it is indicated

[a] See Kentucky Geol. Survey, Eastern coal field, 1884, sections 1 and 4, Pl. II; 5, 7, and 8, Pl. III; 9, Pl. IV; 19, Pl. VI; 25, Pl. VIII.
[b] Ibid., p. 30.
[c] Ibid., p. 32.
[d] Ibid., p. 33.
[e] Ibid., p. 43.
[f] Ibid., sec. 7, Pl. B.
[g] Ibid., p. 43.
[h] Ibid.

at Indian Run and Hunnewell, both in Greenup County. Coal 5 shows under shale at Willard. Coal 6 has an under fire clay at Willard, Keyes Creek, and Turkey Pen Creek, Boyd County, also at Horse Branch, near Catlettsburg, Boyd County. Under coal 7 fire clay occurs at Fourmile Creek, Boyd County; clay or shale underlie it at Star Furnace, East Coalton, and Willard, Boyd County. Coal 8 carries an under clay at Blaine Falls, Lawrence County, and at Willard. The thickness of these beds seems to range in most cases from 2 to 3 feet.

In Menifee County[a] the Coal Measures in the western part of the county are represented by shale series and by the Conglomerate sandstone. In Greenup and Carter counties these shales are present, though they are not always separated from the shales above the conglomerate, the Conglomerate sandstone being entirely wanting near the Ohio River in places, but becoming prominent to the southwest. In that region the section includes a thick bed of nonplastic fire clay associated with limestone, ore, and coal. The fire-clay bed seems to fall off in importance in proportion as the Subconglomerate shales become more prominent, and few traces of it are found in this region.

Fire clay accompanies many of the coal seams in parts of Jackson, Pulaski, Laurel, and Rockcastle counties, but is not worked.[b]

UPPER FERRIFEROUS LIMESTONE.[c]

This carries a bed of ore which in Greenup, Carter, and Boyd counties is usually overlain by a heavy bed of white marl or fire clay which sometimes directly overlies the ore, especially where the limestone is absent. At Amanda Furnace[d] the ore is overlain by two or three beds of fire clay of different quality, from 10 to 15 feet thick in all. This clay is largely used for the manufacture of fire brick at the Bellefonte works and for potters' use in Cincinnati. The following section is given from one of the beds back of Amanda.

Section near Amanda, Ky.

	Feet.	Inches.
Soil	4	0
Clay shales	6	0
Coal		4
No. 2 fire clay	3	0
Potter's clay	4	0
No. 1 fire clay	3	0
Limestone ore		8
Top of limestone	0	0

[a] Kentucky Geol. Survey, Eastern coal field, 1884, p. 201.
[b] Geologic Atlas U. S., folio 47, London.
[c] Kentucky Geol. Survey, Eastern coal field, 1884, p. 140.
[d] Ibid., p. 141.

ANALYSES OF EASTERN KENTUCKY CLAYS.

The following analyses are of clays from eastern Kentucky:

Analyses of clays from eastern Kentucky.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
SiO_2	48.56	45.96	54.62	62.46	45.56	64.26	66.06	62.68	43.58
Al_2O_3	37.471	38.531	32.466	27.203	43.775	24.604	23.726	14.803	40.86
Fe_2O_3	Tr.	Tr.	Tr.	Tr.	Tr.	Undet.	Undet.	6.16	.76
CaO	.112	.145	Tr.	Tr.	.145	.538	[a].30	[a]8.28	.29
MgO	Tr.	Tr.	Tr.	Tr.	Tr.	.209	[a].121	[a]1.65	.14
P_2O_5	.255	.563	.243	.147	.307	.946	.127	.217	.....
SO_3	Undet.	Undet.	Undet.	Undet.	Undet.	.157	Undet.	.....	.....
K_2O	.289	.25	.212	1.85	.963	.751	2.093	3.108	.19
Na_2O	.283	.341	.679	.584	.728	.515	2.273	.149	.05
Ignition	13.03	14.21	11.78	7.756	8.522	8.30	5.30	2.953	14.43

	10.	11.	12.	13.	14.	15.	16.	17.	18.
SiO_2	44.84	41.28	41.58	49.68	62.92	66.56	47.06	67.70	55.56
Al_2O_3	40.18	40.56	38.38	35.281	20.735	22.679	36.62	22.092	31.027
Fe_2O_3	1.76	4.42	4.04	Tr.	3.82	Tr.	Tr.	Tr.	Tr.
CaO	.21	.60	.21	.213	.213	.157	.615	.101	.325
MgO	.13	.17	.10	.136	2.281	.605	.389	.285	.403
P_2O_5	.....	.....	.....	.626	.371	.563	.626	.498	.358
SO_3	.....	.....	.....	Undet.	Undet.	Undet.	Undet.	Undet.	Undet.
K_2O	.17	.11	Tr.	.193	2.601	1.946	1.156	1.156	1.167
Na_2O	.06	Tr.	Tr.	.211	.659	.69	.234	.268	.56
Ignition	12.65	12.86	15.69	13.66	6.40	6.80	13.30	7.90	10.60

	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.
SiO_2	47.56	59.10	84.76	54.18	51.66	69.26	70.86	62.76	40.14	56.44
Al_2O_3	40.661	29.76	11.40	25.36	15.56	16.64	19.24	26.42	43.72	28.00
Fe_2O_3	Tr.			4.82	7.68	4.52	3.12	1.58	1.98	
CaO	.28	Tr.	Tr.	.549	7.269	Tr.	Tr.	.325	1.60	1.30
MgO	.497	.72	.65	1.614	.817	.893	.425	Tr.		
P_2O_5	.249	.....	.....	.....	Undet.	Tr.	Tr.	Undet.		
SO_3	Tr.	.....	.....	.....	.....	.....	.....	.....		
K_2O	.308	3.86	1.58	4.286	3.276	3.102	2.351	.916	12.56	14.30
Na_2O	.409	Tr.	.05	.348	.293	.210	.253	.268		
Ignition	10.036	6.56	1.56	9.80	13.445	5.375	3.751	7.731		

[a] Determined as carbonate.

1. Ridge between Grassy and Three Prong creeks, Boone Furnace property, Carter County, 8 to 10 feet. Kentucky Geol. Survey, Chem. Anal., Pt. I, p. 43.

2. Same locality, lower bed.

3. Same locality, rougher part of upper layer.

4. Fire clay under coal, Old Orchard diggings, Boone Furnace property. Ibid., p. 44.

5. Same bed as 1. Ibid., p. 44.

6. Fire clay under 12-inch coal, G. Osenton's land, near Grayson, Carter County. Ibid., p. 44.

7. Clay shale, railroad cut, one-half mile south of station, Grayson, Carter County. Ibid., p. 44.

8. Washed sample ferruginous marly clay, Limestone station, Carter County. Idem, Pt. II, 1885, p. 181.

9. Fire clay, Perry's branch of Tygarts Creek, near mouth, and near E. L. & B. S. R. R.; bed 9 feet thick. Ibid., p. 276.

10, 11, 12. Same locality.

13. Fire clay, Louder's land, near Kenton Furnace, Greenup County. Idem, Pt. I, 1884, p. 100.

14. Fire clay, 2 feet above limestone ore, head of Powdermill Hollow, 2 miles from Kenton Furnace. Ibid.

15. Clay, fourth above limestone and limestone ore, on Pea Ridge, 2½ feet thick. Ibid.

16. Clay resting on limestone ore, Pea Ridge, near Hunnewell. Ibid.

17. Clay, 2½ feet, second above limestone ore, Pea Ridge. Ibid.

18. Clay, 14 inches thick, third bed above limestone ore, Pea Ridge. Ibid., p. 101.

19. Fire clay, Thomas bank, headwaters of Wings Branch of Shultz Creek. Average sample of upper layer; 5 feet above the cherty limestone. Ibid.

20. Clay, 5 feet thick, on Indian Creek, Whitley County. Idem, Pt. III, 1888, p. 204.

21. Jellico clay, Whitley County. Ibid.

22. Bituminous shale, 5 feet thick, on Knoxville branch of Louisville and Nashville Railroad near Brummitts station. Idem, Pt. II, 1885, p. 309. Burns buff, gray.

23. Shale, below coal at Mud Creek mines, Butler County.

24. Shale, below coal F, mouth of Brush Run on Rough Creek, Ohio County. Idem, Pt. I, 1884, p. 418.

25. Clay from Elm Lick, R. B. Thompson's land. Ibid.

26. Clay from Bald Knob Church, Caney precinct, on Pinchico road, 2 feet below a coal bed. Burns salmon.

27. Upper layer of fire clay used at Ashland.

28. Lower layer of fire clay used at Ashland.

CLAYS OF WESTERN COAL FIELD.

Very little information has been published regarding the clays of the Western coal field. A bed is mentioned near Bald Knob Church, Ohio County, where[a] on B. F. Jenkins's farm the following section is seen:

Section near Bald Knob Church, Ohio County, Ky.

	Feet.	Inches.
Covered space, red clay on surface	5	0
Coal F	0	9
Under clay	3	0
Mottled limestone	1	0
Sandy shale and shaly limestone	28	0
Covered, mostly sandy shale	8	0
Soft, disintegrating sandstone	35	0

[a] Kentucky Geol. Survey, Western coal field, 1884, p. 163.

In Ohio County[a] a hard clay occurs below coal F at the mouth of Brush Run in Rough Creek; also near Elm Creek on R. B. Thompson's land. This is much used at Louisville. Again clay is seen at Bald Knob, on the Pinchico road.

Clay suitable for making vitrified brick has been worked at Cloverport in Grayson County, near Millwood station, on the Illinois Central Railroad. An 11-foot bed is worked for making sewer pipe, and is overlain by 18 inches of coal. The vitrified brick now made at Louisville are a mixture of this clay with a shale obtained 2 miles west of New Albany, Ind.

RECENT, OR ALLUVIAL CLAYS.

Leaving those of the Jackson Purchase region out of consideration, alluvial clays may be looked for in many river valleys where terraces have been formed. They are found in the terraces along the existing streams and are usually very sandy, although often of excellent quality, especially along the Ohio. Shaler states that in various sections along the Ohio he has failed to find any fine-grained clays in the belt of land below the top of the highest water, while the next level, rising, say, 10 feet above this high-water mark, contains very generally, in the district near Covington, at least, a blue-gray clay that is of fair quality.[b] In Clinton County[c] small areas are found along the Columbia River and its tributaries, and are underlain by dark clays. In Henry County[d] deposits valuable for brick making are found along the Kentucky River.

Clay deposits are found in many sink holes of the limestone region, and while the clays may be suitable for pottery, still, owing to their origin, the deposits can never be extensive.

JACKSON PURCHASE REGION.

The clays of this area are so distinct from those found in other parts of the State that they can best be treated by themselves. They have furthermore been dealt with quite fully in a report on the Jackson Purchase region issued by the Kentucky geological survey, from which most of the following facts have been taken.

The Jackson Purchase includes the country embraced between the Mississippi, Ohio, and Tennessee rivers and the Tennessee State line. The geologic section beginning at the top is as follows:[e]

Section in Jackson Purchase region, Kentucky.

ALLUVIUM (of river and creek bottoms).

PLEISTOCENE.

- Brown loam; surface loam of uplands.
- Loess; gray silt of Mississippi bluffs.
- Port Hudson (Hilgard's Louisiana); stiff dark and bluish clays with calcareous concretions under the river alluvium.
- Stratified drift.

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[a] Geol. Atlas U. S., folio 46, Richmond.
[b] Kentucky Geol. Survey, new series, Vol. III, p. 405.
[c] Idem, Report on Clinton County, p. 25.
[d] Idem, Report on Henry County, p. 12.
[e] Idem, Report on Jackson Purchase region, p. 17.

Section in Jackson Purchase region, Kentucky—Continued.

TERTIARY.

Lagrange; stiff plastic clays, variegated in color and interstratified with whitish sand, and carrying leaf impressions.

Lignitic; black arenaceous clay and claystone.

Porters Creek; massive and jointed clays, locally called soapstone.

Hickman; siliceous claystone over a thick bed of buff-colored clays.

CRETACEOUS.

Ripley; black clay in very thin laminæ, separated by fine white and yellow micaceous sands.

LOWER CARBONIFEROUS.

Lower; heavy limestone beds interpolated with dark flint layers.

DEVONIAN.

Massive quartzose sand rocks.

Most of the clays in this part of the State, which we found in all the counties, appear highly refractory before the blowpipe. The classes recognized are:

1. Drab clays of Hickman Bluffs.[a]

2. Siliceous clays from Columbus Bluffs, which face the Mississippi River at Columbus and at the chalk banks below. These rise more than 100 feet above the town. The upper portion is made of 30 feet each of gray silt or loess and gravel. Under the gravel is variegated colored plastic clay 15 feet thick; under this 85 feet siliceous clays. These clays burn hard to a light-creamy color. They are finely siliceous. The clay beds are exposed in the bluffs east of the town. The siliceous clays show in the deep ravine by the Clinton road and the plastic clays in the face of the bluff south of the railroad cut.[b] The siliceous fire clays in places have been cut away, as at the chalk banks, and their places are taken by interstratified beds of fine clay and white sand. The same is true in the bluffs north of Columbus to a short distance beyond Laketon. These were supposed to belong to the Lignitic (Tertiary) group, and are found farther east associated with the belt of dark clay in McCracken and Graves counties.[c]

3. White or light-colored plastic clays. These form beds of greater or less size in each of the counties and are put in what is known as the Lagrange group of the Tertiary. The clay has been deposited since the deposition of the black clays. It usually is white or light purple in color, fine grained, and varies in thickness from a few inches to many feet.

4. Black and bluish-black clays. These are confined to the Cretaceous and the Lignitic or Lower Tertiary belt that passes through Calloway, Marshall, McCracken, and Ballard counties, and to the Port Hudson group of the Pleistocene, which occurs in the valley and bottom land of the three bordering rivers. The dark color is due to vegetable matter. These clays are said to be refractory.

[a] Section given on p. 38 of Report on Jackson Purchase region. [b] Ibid., p. 101. [c] Ibid.

Analyses of white and siliceous refractory clays of Hickman County, Ky.[a]

	1.	2.	3.
Silica	85.18	84.918	76.360
Alumina	10.26	10.56	14.951
Ferric oxide	1.12	1.102	2.109
Lime	Trace.	0.572	0.325
Magnesia	0.064	0.108	0.173
Potash	0.954	0.651	1.171
Soda	0.146	Not est.	0.125
Water, etc	2.276	2.089	4.786
Total	100.000	100.000	100.000

[a] Kentucky Geol. Survey, Report on Jackson Purchase region, 1888, p. 102.

1. Fire clay, bluff above Columbus, Hickman County. Plastic.

2. Clay from bluffs in upper part of town of Columbus, Hickman County. Same bed as 1. Light gray, burns to hard body and light-cream color.

3. Clay from "Chalk banks," 2 miles below Columbus. Burns hard.

Analyses of clays from Hickman Bluffs, Fulton County, Ky.[a]

	1.	2.	3.	4.	5.	6.	7.	8.
Silica	71.340	83.38	71.08	74.10	83.50	77.96	76.86	64.80
Alumina	17.190	9.80	19.05	16.46	9.94	13.97	14.60	21.07
Ferric oxide	2.770	2.12	2.81	2.70	2.50	2.39	3.02	5.27
Lime	1.612	.963	.627	.358	.358	.134	.425	1.40
Magnesia	.209	.187	.403	.187	.173	.163	.308	.05
Potash	.925	.617	.578	.559	.539	.797	.736	.646
Soda	.232	.118	.225	.135	.109	.124	.257	.202
Water, etc	5.722	2.815	5.227	5.501	2.881	4.462	3.794	6.562
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

[a] Kentucky Geol. Survey, Report on Jackson Purchase region, pp. 98–100.

1. Greenish or bluish sandy refractory clay, 1 mile north of Hickman, Fulton County. Burns light gray buff.

2. Greenish to bluish sandy refractory clay, under gravel beds in bluffs in upper part of Hickman, Fulton County, 6 feet thick. Burns light brick color.

3. Refractory clay stone. Burns light gray buff.

4. Slate-colored or bluish refractory joint clay from Hickman Bluffs and under preceding. Burns to hard body of light brown color.

5. Greenish claystone and green refractory clay from Hickman Bluffs. Underlies No. 4. Rather plastic, burns to light brick color. Bed, 10 feet thick.

6. Greenish indurated and refractory joint clay, lower part of Hickman Bluffs. Burns brownish buff. Bed, 50 feet thick.

7. Greenish refractory clay, Hickman Bluffs; 95 feet above low water. Same bed as No. 6. Rather plastic and burns red buff.

8. Indurated clay, Hickman Bluffs, 45 feet above low water. Plastic. Burns light buff and is easily fusible.

Analyses of refractory, white, and light-colored clays from Jackson Purchase region, Kentucky.[a]

Locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Potash.	Soda.	Water.	Color when burned.	Shrinkage.
										Per ct.
White pipe clay, 3 miles east of New Providence, Calloway County.	61.680	28.500	1.680	0.101	0.136	1.158	0.822	5.923	White, unglazed.	.....
White plastic clay, 6 miles northeast of Murray, Calloway County.	57.840	30.340	1.180	.011	.050	.618	.519	9.442	Cream	.....
White clay, 1 mile east of Wyatt's schoolhouse, Calloway County.	46.020	38.980	Tr.	.773	.136	.309	.172	13.610	Brown, white when glazed.	.....
Howard's pottery, Bell City, Graves County; 6–10 feet.	56.980	32.160	2.160	Tr.	.209	.838	.111	7.542	Cream	.....
Stiff plastic clay, 10–15 feet	62.680	25.880	2.900	Tr.	.319	1.147	.928	6.146	White, unglazed.	10
Panther Creek, 6 miles east of Mayfield, Graves County; plastic.	75.550	16.751	1.198	Tr.	.114	1.094	.216	5.047	Salmon	.....
Fire clay, Wickliffe, Ballard County; 10–12 feet.	73.240	15.760	1.920	.325	.519	1.467	.147	6.622	Buff	.....
Refractory white clay, one-half mile northwest of Blandville; bluish white.	74.840	16.580	1.400	.269	.209	1.293	.283	5.126	White	.....
White plastic clay, Cane Creek, 2 miles north of Wickliffe, Ballard County.	63.840	26.040	.740	Tr.	.137	.714	.207	8.822	.....	.....
Clay, T. D. Campbell, Laketon, Ballard County; purplish gray.	67.501	23.051	2.109	.257	.065	.412	.020	6.585	.....	.....
Samuel farm, 4 miles south of Blandville, Ballard County.	71.940	20.700	Tr.	.370	.350	.630	0 0	6.200	White	.....
Plastic clay, G. Ryan, 4 miles northeast of Milburn, Ballard County 4 feet.	76.540	14.720	.960	Tr.	.331	.926	.229	6.194	Light gray	.....
Bluish plastic clay, 3 miles east of Blandville, Ballard County; 3 feet.	71.180	20.800	1.780	Tr.	.101	.247	.291	5.601	.....	.....
Micaceous clay, 5 miles north of Benton, Marshall County.	84.580	10.650	.330	.137	.101	.954	.292	2.956	Dark cream, glazed.	10
Micaceous clay, 2 miles east of Palma, Marshall County; plastic.	62.920	29.880	Tr.	Tr.	.209	1.564	.172	5.255	.....do	15
Five miles south of Paducah, McCracken County; bluish, plastic.	64.480	24.691	1.809	.448	.137	1.457	.083	6.835	.....	.....
Refractory, Moore's Mill, 1 mile southwest of Blandville.	74.460	18.070	1.633	.314	.245	.940	.021	4.317	Dark buff.	15

[a] Kentucky Geol. Survey, Report on Jackson Purchase region, p. 103 et seq.

Clays which are easily fusible are found in a number of the counties, but are said to be confined chiefly to those on the eastern side of the Jackson Purchase region, namely, in McCracken, Graves, Marshall, and Calloway counties. They vary in color from nearly white to black. Some are highly gypseous, while others are sprinkled with vivianite. They are pre-Pleistocene, and are overlain by gravel, sand, and brown loam of that period. They include some of the white varieties belonging to the period intermediate between the Tertiary and Pleistocene and the black clays of the next higher or Port Hudson group.

Analyses of nonrefractory clays from Jackson Purchase region, Kentucky.[a]

Locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Potash.	Soda.	Water.	Color when burned.	Shrinkage.
										Per ct.
Stiff clay, 4 miles south of Paducah.	59.50	24.96	.72	.325	.396	1.934	.286	11.879	Buff	15
Gypseous clay, 4 miles southwest of Paducah.	67.58	20.04	.54	[b]1.743	.158	1.34	.075	8.524	Dark cream	12½
Purplish plastic clay, 3 miles east of Lovelaceville, McCracken County, 3 feet thick.	66.32	22.93	1.19	.437	.209	1.107	.470	7.377		
Stiff plastic clay, railroad cut south of Guill Hill and 3 miles south of Wingo, Graves County.	75.12	15.96	1.42	Tr.	.317	1.351	.248	5.587	Brown	7½
Plastic clay, north of Boaz station, Graves County.	61.92	30.060	.30	Tr.	.064	1.602	.239	5.815	Milk white, unglazed.	
Plastic clay, just south of Scale, Marshall County.	52.58	31.07	1.51	.137	.245	1.775	.318	12.365	Buff, when glazed.	
Dark clay, Tennessee River landing, Highland, Marshall County.	60.98	18.48	7.50	.78	1.128	2.664	.627	7.841	Dark red	
Blue micaceous clay, west edge of Paducah, McCracken County.	73.192	16.54	1.84	.369	.461	1.969	.541	5.088		
Micaceous clay, ¼ mile east of Baring's ford, Clark River, or 7 miles southeast of Paducah, McCracken County.	69.22	17.54	1.14	.437	.858	2.452	.472	7.581	Brick red	12

[a] Kentucky Geol. Survey, Report on Jackson Purchase region, 1888, p. 113 et seq.
[b] As gypsum.

Ocherous clays.—Yellow ocherous clays occur at many points in the Jackson Purchase counties and have been used locally for paint. On burning they oxidize to a bright red. In addition there are certain bluish clays which burn to a good red. One of these beds outcrops in the banks of the Tennessee River at Highland Landing, Marshall County. In Ballard County they are prominent near Wycliffe and Laketon, being exposed in ravines. Another bed of ocher is known in McCracken County, one-half mile east of the boring on Clarks River, 7 miles from Paducah. It burns a deep red. Still another lies at Wadesboro in Calloway County.

Analysis of yellow ocher from Harkless place, north of Wycliffe, Ballard County, Ky

	Per cent.
Silica	44.840
Alumina	22.831
Ferric oxide	20.350
Lime	.101
Magnesia	.138
Water	11.740
	100.000

Since the clays of this area are so important commercially, it seems desirable to mention them in some detail.

Fulton County.[a]—The bluffs at Hickman and southward to the Tennessee line contain much pure clay free from coarse sand and iron pyrites which, it is claimed could be used for the manufacture of tile, terra cotta, and pottery. White and bluish pipe clay occur between the sands of the Lagrange group in the eastern part of the county, but are covered too deeply by Pleistocene sands and loams to render their working profitable, unless worked by drifts.

Hickman County.[b]—Pottery clay is prominent in the bluffs at Columbus and other points bordering the Mississippi. The clays belong to the Tertiary beds proper, while those of the Lagrange group, which have been analyzed, appear as white plastic strata in heavy beds of white sand. Less plastic clays occur in the bluff east of Columbus. Two potteries at Columbus have used the blue clay from the base of the sand and clay from the bluff just north of the chalk banks.

Ballard County.[c]—Many exposures of white and variegated clays occur in the central and southern portions of the county, some of these being refractory. No exposures have been observed north of Cain Creek and Hinkelville. The clays which may be considered most valuable are those in the western part of the county, exposed in the bluffs along the Mississippi and in the banks and river bottoms tributary to that stream. They vary from dark-gray or black clays of the Lignitic group to whitish and more plastic varieties of the more recent or Lagrange group. The former are exposed at the base of the bluffs along the Mississippi bottom from Laketon to Wycliffe, along Mayfield Creek to and beyond Blandville, along Cain Creek north of as well as in the creek bottom in the flats to the eastward of Wycliffe and in an isolated bed 2 miles west of Milburn. For the most part they are covered deeply by Pleistocene gravel and soil. In the neighborhood of Wycliffe there is less covering. These dark lignitic clays are several feet thick and are siliceous and refractory, thus resembling those of the Columbus Bluffs. (See analyses, p. 127.) Their use for fireproofing is suggested.

Second clays, or whiter and more plastic clays, are not extensively found in this county, their beds being mostly thin. They are seen in the high bluffs from Laketon southward and at a few points in the eastern part of the county. An outcrop is 1 mile north of Blandville, and a few miles south of the same town. They have no great value.

McCracken County.[d]—The clays in the county vary from black to white, and are usually distributed according to geologic formations. The black clays are found in the Cretaceous and also in the Tertiary (Eocene) belts in the eastern and middle parts of the county. Those of the former outcrop in the banks of Clarks River

[a] Kentucky Geol. Survey, Report on Jackson Purchase region, 1888, p. 214.
[b] Ibid, p. 225.
[c] Ibid, p. 241.
[d] Ibid., p. 256.

above the railroad bridge and are highly micaceous in character. They have no value. The Tertiary black clays, overlying these, also occur in the Clarks River bluffs, with an exposure of about 15 feet, and again at the foot of the hills south of Paducah. Although only 12 feet thick here, to the northwest or west of Paducah the thickness is as much as 90 feet. An analysis of some clay taken out of the same belt near Murray, Calloway County, is given in the table on p. 127. This same clay is found 5 miles south of Paducah, and at Florence station. Also on the east side of Clarks River.

The whitish clays belong almost entirely to formations later than the Lignitic (Lower Tertiary), and in this county are exclusively found in the central and western portion. The Lagrange group comprises most of the beds. This would include the clay 4 miles southwest of Paducah, on the Hough place, and farther southwest on the place of Dr. Roof, and of Mrs. Annie Grief, 10 miles from Paducah. Also in the north bluff of Mayfield Creek.

Marshall County.[a]—The clays comprise grayish-black joint clay of Tertiary age, and more recent, plastic, lighter-colored and more or less refractory pipe clays, together with a thinly laminated, dark, and micaceous Cretaceous clay, which is exposed in the beds on the sand hill north of Benton. This same clay outcrops also below the foot of the belts bordering Clarks River bottom near Sharps post-office. Black joint clay is found west of Benton, forming a part of that belt which reaches from Murray, Calloway County, on the south, into McCracken County, on the northwest.

The plastic clays of variegated white to purple color are found chiefly east of the belt of black clay just mentioned. The blue clays referred to as occurring in the valley of the Tennessee River are well exposed at Highland Landing. A section of the river bank, beginning at the top, shows:

Section of bank of Tennessee River at Highland Landing, Ky.

	Feet.
Surface covering, light brownish micaceous loam	7
Light-bluish clay, laminated with yellow sands	15
Blue, micaceous, in layers 1 to 2 feet thick, with yellow sand between.	10

Graves County.[b]—White pipe clay is abundant throughout the county, and is penetrated by almost all wells that reach below the gravel beds. It outcrops frequently in the damp ravines. Along the line of railroad from northern part of county southward many good clays are exposed in the cuts, especially north of Boaz, but no thick clays are exposed until within 2½ miles south of Wingo. The clays in the next or "big" cut are of white, purple, and yellow colors and somewhat sandy.

[a] Kentucky Geol. Survey, Report on Jackson Purchase region, 1888, p. 277.
[b] Ibid., p. 294.

They are again exposed 3 miles north of Water Valley, and outcrop to that station and Fulton on the State line.

Calloway County.[a]—A great variety of clays occurs within the county. These are both refractory and nonrefractory, and many are well situated for workings. The black joint clays occupy a belt from the Tennessee line northward through Murray and Wadesboro, into Marshall County, being exposed at a number of points along the west side of Clarks River. They are exposed in the southern part of the county west of New Providence. A prominent exposure is at the Paris bridge 1 mile south of Murray. Other exposures are seen in the bluffs of creeks north of Murray, and in the ravines that border the road north to Wadesboro. They are from 10 to 20 feet thick.

White pipe clays are abundant and found chiefly on the east and west of the black joint clay belt. A highly plastic white variety is found near Mayfield, in sec. 4, T. 3, R. 3 E. The same clay appears in the branch south of this place and also in the bluffs east of the river, at Backusburg, to the east of Murray. On a line passing through it north and south are several beds of white clays, notably at Russell's pottery. They burn to a good color, but difficulty was experienced with the crazing. Another locality of white clay is in the river east of New Providence.

CLAY-WORKING INDUSTRY.

The value of the industry of this State in 1900 and 1901 was as follows:

Value of clay products of Kentucky in 1900 and 1901.

	1900.	1901.
Common brick	$608,334	$621,756
Front brick	21,098	16,535
Vitrified brick	(b)	(b)
Fancy brick	(b)	(b)
Fire brick	393,220	377,741
Stove linings	(b)	(b)
Draintile	26,727	29,498
Sewer pipe	(b)	(b)
Terra cotta	(b)	(b)
Fireproofing	(b)	(b)
Red earthenware	21,202	139,697
Stoneware	110,295	

[a] Kentucky Geol. Survey, Report on Jackson Purchase region, 1888, p. 312.
[b] Product included in other States.

Value of clay products of Kentucky from 1895 to 1901.

Year.	Total value.	Rank.	Proportion of United States product.
			Per cent.
1895	$839,198	19	1.29
1896	829,684	18	1.34
1897	806,368	17	1.29
1898	988,390	15	1.38
1899	1,358,428	14	1.42
1900	1,481,324	12	1.54
1901	1,514,543	18	1.37

Common brick, fire brick, and stoneware are the most important clay products manufactured by the State. Brickyards are located at many localities, especially Ashland, Covington, Louisville, and Paducah. Wall tile are made at Covington, chiefly from clays obtained in other States. Paving brick are made at Louisville from a mixture of Indiana shale and low grade Kentucky fire clay. Fire brick are produced at several places from local clays. About 12 potteries are in operation, most of them located in the western part of the State. They obtain their material chiefly from Tertiary clays.

There is, no doubt, an abundance and variety of raw clay and shale in Kentucky, but distance from the more important markets, together with the fact that neighboring States on the north and northeast also contain a wealth of clay, and are therefore dangerous competitors, will interfere with the rapid development of her clay resources. With the increasing industrial development of the region to the south and west of Kentucky, good markets should be found for the disposal of her clay wares.

MAINE, NEW HAMPSHIRE, AND VERMONT.

The larger portion of these three States is underlain by either pre-Cambrian crystalline rocks or metamorphosed Paleozoic formations, consequently little clay is to be looked for in such areas. Covering the entire surface of these States, however, is a mantle of Pleistocene deposits, mostly glacial drift, which is employed at many places for the manufacture of bricks, as it often contains clayey members. None of the deposits are refractory, and indeed, they may often be quite calcareous. The glacial clays are found in the till or have accumulated in hollows, but in addition to these there are to be found a series of estuarine deposits, represented by the clay beds that have been formed in the larger valleys during a sinking of the land, and consequent drowning of these valleys, in post-Glacial time. The deposits of this character are usually more persistent and thicker than the preceding type of drift

clays. They are found especially in the larger valleys. They also underlie the terraces along the eastern shore of Lake Champlain, where they reach a height of several hundred feet above sea level.

A rather important series of residual clays is found in Vermont in connection with the deposits of manganese and iron ore. These materials are of residual character, and are said to occur[a] at Brandon, Monkton, and Bennington, as well as in Shaftsbury, Wallingford, Plymouth, and Chittenden. They have been worked in past years for the manufacture of porcelain, stoneware, fire brick, and paper, but now are dug chiefly for the paper trade. Some of them are very white in color, others are often ferruginous. The following is an analysis of clay from the mines at Forestdale, Vt., which are worked by the Brandon and Montreal China Clay Company:

Analysis of clay from mines at Forestdale, Vt.

	Per cent.
Silica	53.70
Alumina	35.12
Iron oxide	.06
Lime	Trace.
Magnesia	Trace.
Loss on ignition	10.55
Alkalies, by difference	.57
Total	100.00

The products manufactured in these three States consist chiefly of common brick and earthenware. Where higher grades of ware are manufactured the raw materials used are obtained entirely or in large part from other States. The following tables give the production for the year 1900:

Value of clay products of Maine, New Hampshire, and Vermont in 1901.

	Maine.	New Hampshire.	Vermont.
Common brick	$407,354	$741,589	$61,554
Front brick	22,350	(b)	.....
Vitrified brick	(b)	.....	.....
Fire brick	(b)	(b)	.....
Drain tile	3,830	.....	(b)
Sewer pipe	(b)	.....	.....
Fireproofing	.....	.....	.....
Miscellaneous	.....	.....	16,000
Pottery	(b)	(b)	.....
Total	734,678	765,964	77,554

[a] Geol. of Vermont, Vol. II, p. 802.

[b] Product obtained from less than three firms, and hence can not be given.

MARYLAND.[a]

The clay deposits of Maryland are found in formations ranging from the Algonkian to the Pleistocene, and the several formations are each more or less limited to one of the three topographic provinces into which the State is divisible—the Coastal Plain, the Piedmont Plateau, and the Appalachian region.

The Coastal Plain area contains the Pleistocene, Neocene, Eocene, Cretaceous, Juratrias, and some of the Algonkian formations, and forms a tract extending across the State from northeast to southwest, being bounded on the southeast by the Atlantic Ocean and on the northwest by a line passing from Wilmington through Baltimore to Washington. Although rather flat, still the numerous small streams which dissect it afford many good exposures of the underlying formations.

The Piedmont Plateau region, which extends from the western boundary of the Coastal Plain to the Appalachian Mountains, is characterized by broken, hilly country with undulating surface, and is crossed by numerous rivers which cut into the underlying formations. Within this area the clays are obtained partly from the Paleozoic and to a less extent from the Mesozoic and pre-Cambrian formations. The first two yield shales, while the third gives a series of residual clays which may at times be of value. Where the Paleozoic rocks have been metamorphosed, however, into slates and schists, they are seldom of any value to the clay worker in their unweathered condition. In the eastern part of the Piedmont Plateau region we find considerable areas of metamorphic rocks, such as gneisses, and also of igneous rocks, such as granites and gabbros, which yield residual clays, often of a ferruginous character.[b] In the western portion of the Piedmont Plateau the Cambrian and Silurian rocks cover considerable areas in Frederick and Carroll counties, and by their decomposition yield residual clays.

The Appalachian region consists of a series of parallel mountain ridges composed of upturned Paleozoic strata. Here the shales are contained partly in the Devonian and partly in the Carboniferous rocks, which are abundant in Allegany and Garrett counties.

ALGONKIAN RESIDUAL CLAYS.

The residual Algonkian clays have attracted considerable attention, especially in Cecil County (Pl. IX), for the reason that they have been derived from feldspathic gneiss that contains but little iron, so that the plastic product is of white color and burns to a similar tint. While there are many prospect holes in the kaolin deposits around Northeast and at other points in Cecil County, still there is only one clay-washing plant in operation. Field tests show that the amount of overburden varies, as does also the depth of the kaolin deposit, but that there is no doubt a large

[a] Ries, H., The clays of Maryland: Maryland Geol. Survey, Vol. IV.

[b] For map showing distribution of these, see Maryland Geol. Survey, Vol. IV, Pl. LVIII.

quantity of the material awaiting exploitation and development. The material always requires washing, and where washed the product amounts to about 30 per cent of the quantity mined. In the Maryland clay report already referred to a number of occurrences of kaolin are mentioned.[a] Farther south an important deposit of residual clay has been opened up along the Baltimore and Ohio Railroad, 1 mile northeast of Dorsey station, Howard County. It contains too much iron to permit its being used in the manufacture of whiteware, and is consequently sold in its crude condition for making a refractory brick.

IMPURE RESIDUAL CLAYS.

In addition to the kaolins, there are a number of residual clays found within the State which have been derived from various geologic formations, and occur at many localities in the Piedmont Plateau. They are usually ferruginous, and hence burn red, and even in their natural condition often show brilliant tints of yellow, brown, or red. These residual clays may have been derived from the granites, gabbros, serpentines, gneisses, shales, limestones, and schists. They vary in thickness, and, except in the case of the limestone residuals invariably pass by slow gradation into the parent rock below. The clay obtained from the gabbros and other dark-colored igneous rocks is usually extremely plastic and may show a very high tensile strength. The areas in which these are found are: (1) The Stony Forest area in Harford and Cecil counties; (2) a belt extending from Conowingo on the Susquehanna, in a south-southwest direction to Baltimore; (3) an irregular area beginning west of Baltimore and extending as far south as Laurel. These dark ferruginous clays are used for brick making at several points, and in some cases also for pottery. The granites which also yield ferruginous clays form extensive areas around Port Deposit, Woodstock, Ellicott City, and Guilford.

There are a number of crystalline limestones in Baltimore and Harford counties, but owing to the fact that they are magnesian in character they form a sand on weathering rather than a plastic clay. To the west, however, in Washington County, there is a broad belt of Shenandoah limestone about 16 miles wide, extending across the State in a northeast-southwest direction, which gives an abundance of brick clay when weathered.

SILURIAN SHALES.

These with few exceptions have no value in Maryland for the manufacture of clay products, unless they have weathered to residual clays. The reason for this is that in most cases the beds have been too much altered by folding. One of the few exceptions is the Clinton shale, which outcrops on the hill above the cement works at Pinto.

[a] Maryland Geol. Survey, Vol. IV, p. 458.

DEVONIAN SHALES.

These are represented in Allegany and Garrett counties by a great series of shales, sandy shales, and shaly sandstones. In some cases the shales have been so altered by folding that they develop little or no plasticity when ground and mixed with water, while at other times they are of excellent value for the manufacturer of clay products. Of the several subdivisions the Hampshire, or uppermost one, while of considerable thickness, is of little value, for the reason that the shales are in most cases too siliceous to make a good product. In the Jennings formation, however, the shales are in many places capable of utilization. They are well exposed east of Cumberland, and have there been used for the manufacture of paving brick, for on grinding and mixing with water they form a plastic mass that has a body of a good density and burns to a good red color.

CARBONIFEROUS SHALES.

These are found in the western part of the State in Garrett County and western Allegany County, and are divisible into a number of different formations. The shales are sometimes refractory, but more often are not so. None of the beds except the fire clays are being used at the present time. The Dunkirk formation, which overlies the Waynesburg coal, contains a number of shales, some of which outcrop near Frostburg, but none of them seem to mellow down rapidly to a clay. In the Monongahela formation, whose limits are marked by the Waynesburg coal above and the Pittsburg coal below, there are a number of beds of sandstone and shales, the latter being both sandy and clayey. It is doubtful whether they would be suited to the manufacture of brick without being weathered.

Mauch Chunk formation.—This is perhaps the richest formation in the State in shales, and is consequently of the greatest interest to the clay worker. It flanks the ridges of western Allegany and eastern Garrett counties, and grades gradually downward into the Greenbrier deposits. The formation is composed chiefly of red shales, which are interbedded with reddish-brown sandstones. In places these shales are mellowed down to a plastic clay of red color. Both the Greenbrier and the Pocono formations, which lie under the Mauch Chunk, are of little value to the clay worker.

The Mount Savage fire clay, which occupies a well-marked stratigraphic position, is a deposit of great value, for it possesses high refractory qualities. It is fortunate that its stratigraphic position is known, for, owing to the heavy covering in the region of Allegany and Garrett counties, outcrops of it are very scarce. It has already been opened up at two points on Savage Mountain, which are west of Frostburg and Mount Savage, and also on the Little Allegheny Mountains west of Ellerslie. The deposit is also found outcropping near Blaine and at Swallows Falls.

Garrett County. The bed sometimes contains flint clay and sometimes plastic shale clay. The analyses and tests of the material are given in the table on pages 145–147.

Pottsville formation.—The Pottsville formation is the only one of the Carboniferous formations which has been commercially exploited for clay in Maryland, for it contains valuable deposits of fire clay whose position is indicated by the following section, measured in Pennsylvania just north of the Maryland line.

Section of Pottsville formation.

	Ft.	In.
Massive sandstone	75	0
Mount Savage coal	4	0
Mount Savage fire clay	7	6
Conglomerate sandstone	125	0
Dark shaly sandstone	10	0
Shale	1	0
Coal and shale		8
Impure fire clay	10	0
Dark shales with iron ore	20	0
Massive sandstone	35	0
Total	288	2

Allegany formation.—The Allegany formation underlies the Conemaugh and outcrops on the eastern side of the Georges Creek coal basin, high up on the western slope of Dans and Little Allegheny mountains. It contains many beds of shale, as can be seen from the following section:

Section at Franklin village, Allegany County, Md.

Massive sandstone:	Feet.
Greenish shaly sandstone	55
Massive sandstone	24
Ferruginous shale, showing spheroidal weathering	3
Thin black and brown shales	8
Grayish-green shale	10
Fine grayish-green shale	4
Arenaceous shale	9
Greenish sandstone and shale	26
Shaly sandstone	6
Fine shale and concealed	9
Shaly sandstone	13½
Concealed	30
Coal [Davis]	6
Sandstone, shale and concealed	7
Flaggy sandstone	16
Massive sandstone	4
Shale	2
Coal ["Split-six"]	3
Concealed	90

None of these shales are at the present time being used, but some of them appear promising. Even though they might not be used for bricks, they could perhaps be used in the manufacture of Portland cement.

Conemaugh formation.—This formation, formerly called the Barren Measures, contains many shale deposits, with the Mahoning sandstone at the base. The shales are usually argillaceous and are sometimes associated with coal. The following section from the upper part of the formation is found along the Potomac gravity plane, in Allegany County, and illustrates the general sequence of the beds.

Section at the Potomac plane, Allegany County, Md.

	Ft.	In.
Black shale		10
Very coaly shale		3
Black, somewhat coaly shale	1	8
Impure coal	2	8
Black shale with very thin coal streaks		4
Coaly shale	1	1
Coal, apparently all good	2	4
Shale, dark above, gray lower down	1	5
Clay		7
Massive bluish-gray argillaceous limestone	2	1
Massive light-gray argillaceous brecciated limestone	1	9
Very argillaceous limestone	4	6
Soft, weathered shale		4
Iron-ore band		4
Black, coaly shale	2	0

Some of the shales which were tested developed fair plasticity. None of them showed refractory characters.

CRETACEOUS AND JURATRIAS CLAYS.

The deposits of Cretaceous and Juratrias age underlie large areas in Maryland and are perhaps the most important series of clays in the State. The subdivisions of the Cretaceous are as follows:

Cretaceous and Juratrias formations of Maryland.

Upper Cretaceous	Rancocas.	
	Monmouth.	
	Matawan.	
Lower Cretaceous	Raritan.	Potomac group.
	Patapsco.	
Juratrias (?)	Arundel.	
	Patuxent.	

The Upper Cretaceous deposits of Maryland, which are a continuation of similar large beds in Delaware and New Jersey, cross the State from northeast to southwest, being developed in Cecil, Kent, Anne Arundel, and Prince George counties. They bear little clay and at the present time no pits have been opened in them. Those of the Potomac group, or Lower Cretaceous, are highly important, however. This group consists of a series of sands, sandy clays, and gravels which have been deposited at different periods and under varying conditions, the result being that the most unlike materials passed into each other horizontally. In vertical sections the most contrasted materials may overlie one another. The general dip of the beds is slight and ranges from 30 to 50 feet per mile to the southeast. Although the dip is fairly uniform, still the different members of the Potomac group have no well-defined upper and lower limits, or even top. On the contrary, the upper surface of any one member may be very uneven, owing to the fact that it has been much eroded or worn down by water action before the next member above it was deposited, while, therefore, if traced horizontally along the line of strike, any one member might be found at different levels, still the regularity of succession of the different members can be recognized if we follow across the surface at right angles to the line of strike, and thereby encounter successively the outcrops from the lowest to the highest division.

Patuxent formation.—This shows its type development in the upper valleys of the Big Patuxent and Little Patuxent rivers. As it is the basal member of the Potomac group it is naturally found near the landward margin of the Coastal Plain and rests on the crystalline rocks of the Piedmont Plateau. The Patuxent formation can be traced as a narrow, irregular, and sometimes broken belt from Cecil County on the northeast across Harford, Baltimore, Anne Arundel, and Prince George counties to the borders of the District of Columbia on the southwest. While the deposits of the Patuxent are mostly sand, often of high purity, still beds of sandy clay sufficiently plastic for the clay workers' use are occasionally found. Stoneware clays are also at times met with in this formation. The thickness of the Patuxent is estimated at about 150 feet, and it is less important than the Patapsco, Arundel, or even the Raritan. In Cecil County it contains little clay of commercial value, but around Baltimore and in Harford County refractory clays have been found in it near Sewall on the Baltimore and Ohio Railroad. Owing to the sandy character of these Patuxent clays they are usually low in tensile strength, but also show a low shrinkage in drying and burning. Some of them even have been used with much success in the manufacture of terra cotta, being mixed with more plastic Arundel clays.

Arundel formation.—This receives its name from its occurrence in Anne Arundel County, where the deposits of this horizon are well developed. Like the Patapsco, it can be traced as a broken belt the entire distance from Cecil

County to the District of Columbia; or more properly, it may be said to occur as a series of long, narrow belts that extend in a general northwest-southeast direction, forming a low angle with the border of the Piedmont Plateau. The deposits consist of a series of great and small lenses of clays bearing iron ore, which have commonly been deposited in old depressions in the surface of the Patuxent formation. These clays, which are commonly spoken of by the miners as blue charcoal clay, are usually dark colored and very tough, and at times are highly carbonaceous. These lens-shaped deposits of the Arundel formation vary considerably in size and may range in thickness from a few feet up to 125 feet. The following two sections give an idea of the character of the Arundel:

Section at Reynold's mine, Piney Run, Anne Arundel County, Md.

	Feet.
RARITAN:	
White and light-brown sand, gravel containing crusts of iron stone	10
PATAPSCO:	
White and variegated argillaceous sands ("fuller's earth"), etc., "paint rock," at base	10
ARUNDEL:	
Drab-colored, compact, laminated clays containing nodules of ore and also plant impressions	70+
Total thickness	90+

Section of Old Blue Bank, Muirkirk, Prince George County, Md.

	Feet.
PLEISTOCENE:	
Sandy gravel	4
PATAPSCO:	
Mottled, gravelly loam	12
ARUNDEL:	
Massive blue clay	20
Highly lignitic clay, with "charcoal ore"	2
Tough, dry, blue clay, with "white ore"	15
PATUXENT:	
White sand	10+
Total thickness	63

These lenses of Arundel clay are well seen near Piney Run, Anne Arundel County; at Sewall and Joppa, Harford County; on Stemmers Run, Baltimore County; and at Locust Point, Baltimore. The Arundel clays are usually blue in color, often siliceous and of good plasticity, but as a rule do not have high tensile strength. They are used in large quantities for the manufacture of common and pressed brick, terra cotta, roofing tile, and common pottery. On account of the great abundance of iron ore in them it is sometimes necessary to adopt some special means to free the clay from the lumps of this material. Arundel clays are found in the counties of

Cecil, Harford, Anne Arundel, Howard, Prince George, and Baltimore. In the City of Baltimore they are used in the manufacture of sewer pipe, and at Spring Gardens (Middle Branch of Patapsco River), near the same city, the clay has been dug for pottery, being used even in the manufacture of yellow ware. Some refractory clay is obtained from the Arundel formation at Locust Point, near Fort McHenry, and brick clay is dug at Curtis Bay Junction. In fact many of the brickyards around Baltimore use Arundel clay. The clay from this same formation has been dug for terra-cotta manufacture south of Baltimore, and at this point is underlain by a layer of red clay that is used in the manufacture of paint. Aside from these uses the Arundel clays have also been found suitable for the manufacture of Portland cement. Physical tests of these clays are to be found in the annexed table (p. 146). The Arundel formation does not contain any deposits of white refractory clay, such as are found in the Raritan, Patapsco, or the Patuxent.

Patapsco formation.—The typical exposures of this formation are on the shores of the Patapsco River. It is very abundant and extends entirely across the State from the Delaware line to the Potomac River. The Patapsco deposits are chiefly bright-colored and mottled clays, which sometimes occur in much lighter-colored sands and clays. At times they may be ore bearing, and again they are often more or less dark colored and lignitic. The strike of the formation is practically the same as that of the Raritan, and its total thickness is at least 200 feet. A prominent feature of the Patapsco formation are the great banks of red and white variegated clays which outcrop at many points and are known as terra-cotta clays. The Patapsco clays are perhaps more worked than any of the other members of the Potomac group. Thus, bluish stoneware clays are dug from near the base of the Patapsco in Cecil County. The Patapsco also contains a number of deposits of refractory clay, which are usually whitish and sandy in character. These are found in Cecil, Harford, Baltimore, Anne Arundel, and Prince George counties.

The variegated clays occur at so many points that it would be impossible to mention them all in detail, but they are very prominent in Cecil County, northeast of Havre de Grace, being exposed in the cuts along the Pennsylvania Railroad.

Raritan formation.—The deposits of the Raritan consist of sands and clays, the former largely predominating in the upper portion of the formation; in other words, in the eastern and southern portions of the belt in which it outcrops. The clays are usually light colored, and may become variegated, red, or even black. The thickness of the Raritan in central Maryland is estimated as not far from 200 feet, but it lessens in thickness greatly to the south, nearly disappearing in the District of Columbia. The following section of the Raritan on the west shore of Elk Neck, at the Lower White Banks, indicates its character.

Section at Lower White Banks, west shore of Elk Neck, Md.

	Feet.
PLEISTOCENE:	
Gravelly loam	0–6
RARITAN:	
White sandy clay (fuller's earth)	25
Buff and brown cross-bedded sands, brightly iron tinted in the middle and lower portions, containing pebbles of white clay, indurated below	20
Jointed light-drab clay	2
Fine, dense, drab plastic clay, laminated above and obscurely bedded below (conchoidal fracture), rich in exogenous leaf impressions	2
Light-drab and buff laminated clay with filmy partings of fine white sand	2
Light-colored sands, locally consolidated	0–115
PATAPSCO:	
Massive, variegated, and drab clays, mostly covered by talus, to tide level.	

This section does not show much clay, and yet there are localities in which the Raritan may contain an abundance of it. The counties in which the Raritan clays are found are Cecil, Harford, Baltimore, Anne Arundel, Prince George, Howard, and Montgomery. In most of these, especially the eastern ones, there are often beds of white, sandy, fairly refractory clay, known as fuller's earth. Among the important exposures of the Raritan may be mentioned those occurring along the Magothy and the Severn rivers, around the glass pits at the head of the latter river. Up to the present time the Raritan clays have been but little worked.

EOCENE CLAYS.

The Eocene deposits extend across the State in a northeast-southwest direction, forming a belt of varying width, which is greatest in the region of Upper Marlboro, Prince George County. They are composed of several members, as follows:

Eocene deposits of Maryland.[a]

Group.	Formation or stage.	Member or substage.
Pamunkey	Nanjemoy	Woodstock.
		Potapaco.
	Aquia	Paspotansa.
		Piscataway.

These different members involve beds of sand, clayey sand, greensand or marl, but only one containing clay deposits of any importance is the Potapaco. This contains a clay deposit near its base, the material being very characteristic in appearance. It is not found north of South River, but extends from that stream southwestward, showing many good outcrops, among which the following are especially prominent: In the valleys of the Western and Charles branches of the

[a] Maryland Geol. Survey, Eocene, p. 58.

Patuxent; on the road from Davidsonville to Annapolis; halfway between the former locality and South River; at Upper Malboro; also at many points south of Hardesty. It also occurs on the west side of the Patuxent River, in every little cove between Hardesty and Hills Bridge. This red clay is also exposed in the Potomac Valley in Prince George County, and even across the Potomac in Virginia.

It is a fine-grained red material with more or less fine sand and has a thickness of at least 20 feet. It is not worked at present, but could probably be used for pressed brick, but is insufficiently plastic for pottery.

NEOCENE CLAYS.

These underlie a broad area in the eastern portion of the State, and form deposits of considerable thickness. The deposits of this age have been divided into the Lafayette and the Chesapeake formations, respectively the upper and lower members of the series.

The Lafayette consists of gravel, sands, and clays, which are irregularly stratified and often change rapidly within narrow limits, seldom exceeding 25 feet in thickness, rarely being of much value to the clay worker. On the divides in Charles County the Lafayette formation contains a buff-colored loamy clay, resembling somewhat the Philadelphia brick clay in appearance.

The Chesapeake formation contains sands and marls, with only local developments of clay or diatomaceous earth. It is of little economic value to the clay worker.

PLEISTOCENE CLAYS.

These overlie the earlier formations of the Coastal Plain, and in some cases extend up on the rocks of the Piedmont Plateau. They form a mantle of sandy clay, loam, and gravel of various thickness. The loams, which belong to the Columbia group, are very extensive and rarely wanting, so that they form an abundant source of brick-making material which is not overlooked. In most cases the Pleistocene clays underlie terraces at no great elevation above sea level, but up to the present time the Pleistocene clays have been used for nothing except common brick and earthenware. Columbia clays are well developed at a number of points, as in the cut north of Perryville, Cecil County; at the base of Bull Mountain, Cecil County; and at many points around the city of Baltimore not more than 30 feet above sea level. At the last-named locality they are extensively used for the manufacture of common brick, for they are moderately plastic and have sufficient iron to burn to a good red color. In Anne Arundel County they are well exposed in brick-clay pits near Curtis Bay. An important series of Pleistocene clays of higher grade is found outcropping along the shore of Chesapeake Bay from Bodkin Point southward.

Many of these outcrops have been found to be well suited to the manufacture of stoneware, for they burn to a dense body of creamy color, and are often of very fair refractoriness.[a] Other deposits are found in Howard County, north of Savage station; and along the west side of the Anacostia River, especially within the District of Columbia. In the counties of southern Maryland there are considerable deposits of clay of Pleistocene age which could no doubt be used for the manufacture of brick and tile. The deposits are often lens-shaped, some of them similar in appearance to those of Bodkin Point. Important lenses of these clay are found one-half mile northeast of Drum Point, one-fourth mile west of Drum Point, one-half mile south of St. Leonard Creek, 1 mile west of Cedar Point, 5 miles south of Cedar Point, and at other places. Along the eastern shore of southern Chesapeake Bay are scattered clay deposits of Pleistocene age, which are often rather loamy in their character. Pits have been opened near several of the larger towns, especially Centerville, Queen Anne County; Greensboro and Ridgely, Caroline County; Cambridge and Vienna, Dorchester County; St. Michaels and Tilghman, Talbot County; Salisbury, Wicomico County; Crisfield, Somerset County; Berlin and Pocomoke, Worcester County.

ANALYSES AND PHYSICAL TESTS OF MARYLAND CLAYS.

The following tables show the physical properties and chemical analyses of a number of Maryland clay and shale samples:[b]

[a] See table of tests of Maryland clays, pp. 146 and 147.
[b] From Maryland Geol. Survey, Vol. IV, pp. 494–496.

Analyses of Maryland clays.

Locality.	Character.	Age.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Alkalies.	Ignition.	Total.	Total fluxes.
Allegany County:											
Cumberland	Bottom shale for paving brick	Jennings	70.25	17.71	4.10	0.70	0.40	1.76	4.80	99.72	6.96
Do	Top shale for paving brick	do	68.30	17.50	4.00	.80	.65	3.10	5.10	99.45	8.55
Frostburg	Not worked	Conemaugh	51.05	28.60	3.75	3.80	1.24	.50	10.85	99.79	9.29
North of Westernport	do	Allegheny	56.50	22.90	6.37	1.60	1.58	1.60	10.00	99.55	11.15
Mount Savage	Flint clay	Pottsville	56.15	33.295	.59	.17	.115	.....	9.68	100.00	.875
Anne Arundel County:											
Severn River	Baldwin's sandpit, not worked	Raritan	75.40	16.73	1.27	.35	.90	.50	5.30	100.45	3.02
Bodkin Point	Not worked	Pleistocene	69.40	19.70	2.00	.20	.60	.62	7.85	100.37	3.42
Dorsey estate, Severn River	do	Raritan	70.08	23.00	.96	.....	.....	.....	5.96	100.00	.96
Swan Cove, Magothy River	do	do	58.00	19.10	2.80	.93	.08	.80	18.20	[a] 99.91	4.61
Shore below Bodkin Point	Vivianite clay, not worked	Pleistocene	58.10	26.00	3.90	.90	.35	.60	2.40	99.25	5.75
Baltimore	Sewer-pipe clay	Arundel	59.70	27.00	2.10	.60	.52	1.96	8.20	100.08	5.18
Baltimore County:											
Curtis Bay, Baltimore	Brick clay	do	71.55	17.70	2.25	.60	.86	.42	6.50	99.88	4.13
F. Link's pit, south of Baltimore	Terra-cotta clay	do	68.30	21.27	1.43	.52	.80	.20	7.55	100.07	2.95
Cromwell Bros.' brickyard east of Baltimore.	Sandy red clay, 8 feet from top		77.62	12.46	4.10	.52	.46	.....	4.58	100.74	5.08
Do	Less sandy-gray clay, 22 feet from top		72.02	16.66	1.38	.12	.85	.....	6.35	97.38	2.35
Do	Clean blue clay, 38 feet from top		71.66	16.92	1.82	.....	.93	.....	6.14	97.47	2.75
Cecil County:											
Bacon Hill	Grosh stoneware clay	Patapsco	65.70	20.30	1.00	3.50	1.44	.62	7.60	100.16	6.56
Carpenter Point	Stoneware clay	do	72.50	17.00	1.50	.35	.60	1.10	6.50	99.45	3.55
Bull Mountain	Not worked	Pleistocene	76.80	15.00	2.50	.20	.41	.62	5.15	100.68	3.73
Northeast	Kaolin	Algonkian	55.65	30.53	.97	.75	.60	.20	12.30	100.35	2.52
Garrett County:											
Blaine	Flint clay, unworked	Pottsville	45.40	38.90	1.01	.31	Trace.	Trace.	15.20	100.82	1.32
Swallow Falls	Flint clay	do	61.00	26.36	.83	.21	.10	Trace.	11.60	100.04	1.14
Do	Shale fire clay	do	46.10	38.05	1.05	.39	.60	.....	12.95	99.14	2.04
Prince George County:											
Upper Marlboro	Not worked	Eocene	58.60	28.71	3.22	.40	.35	.63	8.90	100.81	4.60
Washington County:											
Williamsport	Dark-red brick clay	Pleistocene	67.50	17.20	6.70	.45	.....	1.76	5.90	99.51	8.91
Do	Light-gray brick clay	do	61.30	22.30	3.80	.70	.....	2.10	8.00	98.20	6.60

[a] P_2O_5 undetermined.

Table showing results of physical tests on Maryland clays.

Locality.	U. S. Geological Survey atlas sheet.	Age.	Rate of slaking.	Tempering, per cent H_2O req.	Shrinkage.			Tensile strength.	Incipient fusion. Cone number.	Vitrification.	Viscosity.	Plasticity.
					Air.	Fire.	Total.					
Allegany County:				*Per ct.*								
Savage Mountain	Frostburg	Mauch Chunk	Slow	19	4	5	9	55	01	4	7	Lean.
Near Franklin	do	Allegheny	do	16	3	5	8	40	1	5–6	.....	Do.
Anne Arundel County:												
Bodkin Point	North Point	Pleistocene	do	30	6	4	10	40	8	27+	.....	Good.
1 mile south of Bodkin Point	do	do	do	35	8	10	18	160–180	1	4	7–8	Do.
2 miles south of Bodkin Point	do	do	Moderately fast	40	11	9	20	223–250	05	2	7	Very good.
Harman, ½ mile south	Relay	Raritan	do	19	4	6	10	60–70	3	8+	.....	Moderate.
F. Link's pit	Baltimore	Arundel	do	22½	6	9	15	77	1	6	10	Good.
Severn River, Brown's	Relay	Raritan	Slow	24	6	10	16	Low.	1-2	10	27	Moderate.
Glass-sand pits	Relay	do	Fast	17	5	11	16	90	3	8	10+	Good.
Baltimore	Baltimore	Arundel	Slow	30	7	11	18	134	1	6	8+	Do.
Baltimore County:												
Rittenhouse, Baltimore	Baltimore	Patapsco	Moderately fast	31	9	11	20	111	05	4	7–8	Do.
Curtis Bay Junction	do	Arundel	do	26½	5	7	12	75	2	8	10+	Do.
Locust Point	do	do	Slow	22	5	7	12	65–70	6	10	27–	Very good.
Cecil County:												
Bull Mountain	Elkton	Pleistocene	do	25	5	5	10	123–134	01	5	7+	Good.
Carpenter Point	Havre de Grace	Patapsco	do	33	6	6	12	110–125	1	8	25	Very good.
Eder	Elkton	do	do	.....	6	8	14	68–75	4	10+	27+	Do.
Grosh stoneware clay	Elkton	do	do	23	6	10	16	110–125	01	8	12–14	Do.
Leslie	Elkton	Residual	Fast	20	2	2	4	10	27	.....	.....	Lean.
Northeast	.....	do	do	18	1½	12½	[a]14	20	10	27	.....	Do.
Northeast River	Elkton	Patapsco	Slow	30	6	4	10	40	8	27+	.....	Moderate.
Shannon Hill	Elkton	do	Moderately fast	20	5	3½	8½	100	3	8	10+	Fair.
Howard County:												
Dorsey	Relay	Residual	Fast	25	4	[b]5	.....	15	27+	.....	.....	Lean.
Do	Relay	Arundel	do	22	5	7	12	60	.....	12	27	Good.
Prince George County:												
Upper Marlboro	E. Washington	Eocene	do	35	9	11	20	132	05	6	10	Fair.

[a] At cone 10.

[b] At cone 8.

Table showing the behavior of a number of Maryland clays heated to cone 27.

Locality.	Sheet.	Geologic age.	Behavior.	Remarks.
Allegany County:				
Mount Savage	Frostburg	Pottsville	Incipient fusion	Flint clay.
Do	do	do	Barely incipient fusion.	Shale.
Anne Arundel County:				
Severn River, Baldwin pit	Relay	Raritan	Nearly vitrified	White clay.
Severn River, Brown pit	do	do	Viscous	Yellowish-white clay.
Earleigh Heights		do	Vitrified	
Deep Run	Relay	Patuxent	Nearly incipient fusion.	
Dorsey estate	do	Raritan	Vitrified	Clay.
Harwood		Residual	do	
Wade estate	Relay	Raritan	Not quite vitrified	
Baltimore	Baltimore	Patapsco	Vitrified	
Baltimore County:				
1¼ miles southeast Mount Winans.	do	do	do	
Cecil County:				
Atkinson Cut	Elkton	Residual	Incipient fusion	Crude kaolin.
Carpenter Point	Havre de Grace	Patapsco	Viscous	Stoneware clay.
Eder	Elkton	do	Nearly viscous	
Do	do	do	Partly vitrified	
Do	do	do	do	
Elk Neck	do	Raritan	Viscous	
Gray's Hill	do	Patapsco	Vitrified	
Leslie	do	Residual	Incipient fusion	Viscous 30.
McKinneytown	do	Raritan	Nearly vitrified	
Northeast	do	Patapsco	Vitrified	
Maryland Clay Co	do	Residual	do	Washed clay.
Northeast River	do	Patapsco	do	
Northeast	do	do	Vitrified at 30	
Do	do	do	Vitrified	
Jackson	Havre de Grace	Residual	Incipient fusion	
Garrett County:				
Blaine		do	do	Flint clay.
Do		do	do	Shale.
Swallow Falls		Pottsville	do	Flint clay.
Do		do	Nearly incipient fusion.	Shale.
Harford County:				
Sewall		Patuxent	Viscous	White, micaceous clay.
Bush River		Patapsco	Incipient fusion	
Howard County:				
Dorsey	Relay	Residual	do	Used for fire brick.
Do	do	Arundel	Viscous	
Prince George County:				
Branchville	East Washington	Residual	Incipient fusion	
Do	do	Patapsco	Vitrified	
Horsepen Run		Raritan	do	

CLAY-WORKING INDUSTRY.

The chief product manufactured in Maryland is common brick, as clays suitable for brick making are found at many localities, being obtained from the Coastal Plain sedimentary clays, the residual clays of the Piedmont Plateau, and the shale deposits of the Paleozoic area. In the Coastal Plain region the Columbia loams are most sought. Comparatively few pressed brick are manufactured within the State, although dry-pressed ones have been made at Baltimore, and re-pressed soft ones are made at Williamstown and several other localities. Paving brick are manufactured from the Devonian shales east of Cumberland, with good success.

The terra-cotta industry of Maryland is comparatively little developed, and yet the results thus far produced are very promising. Buff-colored terra cotta and roofing tile are manufactured in the vicinity of Baltimore from mixtures of the Arundel and Patuxent clays. The variegated Patapsco clay has not been used for this purpose, although beds containing material very similar to it are being made into terra cotta in the vicinity of Washington, D. C. Sewer pipe is manufactured at but one locality, and it is made from a mixture of Arundel clays. The fire-brick industry is of considerable importance within the State of Maryland, the refractory clays being obtained from the Coastal Plains formation, or from the Carboniferous deposits of the Appalachian region. The Carboniferous fire clays of Maryland have been worked since 1841, and the mines on Savage Mountain supply the fire-brick works at Mount Savage, Frostburg, and Ellerslie. Around the city of Baltimore there are fire-brick works which obtain their raw material in part from Pleistocene clays and in part from residual Algonkian deposits. There is an abundance of refractory material, however, in both the Patapsco and the Patuxent. Around Northeast, in Cecil County, there is a considerable development of the stove-brick industry, the raw materials being obtained at no great distance from the works.

Maryland possesses one of the few enameled-brick works in the United States. The factory is at Mount Savage, and the product is made from a mixture of flint and plastic fire clays, which are also used for the manufacture of fire brick at that locality. There are several important white-ware potteries at Baltimore, which have been in operation for a number of years, but, curiously enough, they draw their entire supply of clays from other States. Red earthenware, Rockingham ware, and even stoneware, are made from local clays at several localities near Baltimore, as well as at places in other parts of the State. The relative importance of the Maryland clay-working industry can be seen from the following figures, which give the value of the clay products of Maryland in 1900 and 1901, and also the total production since 1895:

Value of clay products of Maryland in 1900 and 1901.

	1900.	1901.
Common brick	$724,013	$676,708
Front brick	60,729	76,792
Vitrified brick	595	(a)
Fancy brick	9,886	11,000
Fire brick	321,666	342,055
Stove linings	36,049	40,237
Drain tile	2,363	2,402
Sewer pipe	(a)	(a)
Terra cotta	119,938	(a)
Tile		16,586
Pottery	436,617	333,480
Miscellaneous	26,193	12,586

a Less than three producers.

Value of clay products of Maryland from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$1,066,987	13	1.63
1896	1,450,055	10	2.33
1897	1,305,282	11	2.09
1898	1,542,853	10	1.75
1899	1,679,641	11	1.75
1900	1,711,856	11	1.78
1901	1,605,655	13	1.46

MASSACHUSETTS.

The workable beds of clay, with very few exceptions, are confined to the Cretaceous, Tertiary, and Pleistocene formations. The first two occur on Marthas Vineyard and Nantucket, and belong to the same series as those found on northern Long Island and in New Jersey, while the latter are scattered all over the State.

Residual clays are rare.

RESIDUAL CLAYS.

Two remarkable deposits of white residual clay or kaolin are found in Massachusetts. One of these is at Blandford, Hampden County; the other is 4 miles south of Clayton, Berkshire County.

The Blandford kaolin has been formed from the decomposition of a pegmatite vein cutting through mica-schist, having at one point a width of nearly 100 feet.[a] The material has been used at East Russell, 5 miles from Blandford, for the manufacture of white brick and terra cotta, being mixed with New Jersey clays for this purpose. Its composition is as follows:

Analysis of kaolin from Blandford, Mass.

	Per cent.
Silica	52.03
Alumina	31.76
Water	15.55
Magnesia	.54
Ferric oxide	Trace.
Lime	Trace.
Alkalies	Trace.
Total	99.88

The kaolin deposit south of Clayton is large, but has not been described. It no doubt has been derived from the decomposition of quartzite or feldspathic gneiss, and has been worked since 1893 for the manufacture of terra cotta.

Its composition is given below.

Analysis of kaolin from deposit south of Clayton, Mass.

	Per cent.
Silica	50.00
Alumina	44.00
Iron protoxide	1.00
Lime	.024
Alkalies	1.24
Total	96.264

MESOZOIC CLAYS.

The Cretaceous and Tertiary beds form a thick series of clays and sands which are well exposed in the cliffs at Gay Head. Although originally deposited horizontally, they have since been much folded and broken by the continental glacier which advanced against them, so that between their disturbed condition and their rapid variation in character the beds are of little commercial value. Where they are least disturbed, as on Gay Head, the shipping facilities are poor. Here and there in the deposits white or buff clays have been found in pockety form, and these have been dug at several points. These clays have found a limited application for pottery manufacture.

[a] Crosby, W. O., The kaolin in Blandford, Mass.: Tech. Quar., Vol. III, No. 3, Aug. 1890.

PLEISTOCENE CLAYS.

Above the Cretaceous and Tertiary deposits is another series of beds, known as the Weyquosque series, which aggregate 200 feet on the southern side of the island.

The Pleistocene beds are extensive on the islands of Marthas Vineyard, Nantucket, and in southeastern Massachusetts on Cape Cod, but most of these are not well adapted to brick manufacture, as they warp too much in burning. The latter or true glacial clays are found and worked at many points. Some of these were formed in estuaries, others in pools, under or in front of the ice, while still others occur in the morainal drift and represent ground-up rock flour. In the region south and east of a line from the mouth of the Merrimac River to Stonington, Conn., they are not found above an elevation of 100 feet. Around Boston these glacial clays are well developed in the estuaries of the Charles, Mystic, and Saugas rivers north and west of Boston. The clay is bluish, plastic, and very fine, and may at times contain bowlders or scattered pebbles. Around North Cambridge the clays are 82 to 85 feet thick, and are underlain by gravel. These clays are also extensively worked along the Mystic River at Medford; at Cambridge and Belmont, on the Charles River; at Holyoke and South Hadley, on the Connecticut; and at Taunton, on the Taunton River.[a]

Very few analyses have been published of Massachusetts clay, and no physical tests. Such analyses as have been obtainable are given below.

Analyses of Massachusetts clays.

	1.	2.
Silica	48.99	57.50
Alumina	28.90	31.21
Ferric oxide	3.89	.....
Lime	7.1	.19
Magnesia	3.66	.20
Alkalies	4.73	.40
Moisture	3.31	9.83
Total	100.58	99.33

1. Glacial clay, West Cambridge, Middlesex County; J. Card, analyst.

2. Red clay, south end Gay Head section, Dukes County, Seventh Annual Rept. U. S. Geol. Survey, p. 359.

CLAY-WORKING INDUSTRY.

Considering the lack of clay resources in Massachusetts, the State possesses a remarkably varied clay industry. This consequently necessitates the shipping in of

[a] Whittle, C. L., The clays of Massachusetts: Eng. Min. Jour., Vol. LXVI, p. 245.

many clays from other States, chiefly New Jersey, and to a lesser extent New York. Since these raw materials can be sent to the consumer by boat usually, the cost of manufacture is not necessarily great.

Brick are made from local surface clays at a great many localities, notably around Boston, in the towns of Medford, Revere, Cambridge, Belmont, and Everett, as well as at several places in southeastern Massachusetts near Taunton and Bridgewater. In the northeastern part of the State common brick are also made at Newburyport and Danvers. There are also many firms scattered over other parts of the State, most of them supplying a local demand. Pressed brick are made at but few localities outside of Boston. Fancy brick are manufactured at South Boston from a mixture of New Jersey and Gay Head clays. Some glazed brick are also produced.

Many stove linings are made at Taunton from New Jersey materials, while at Chelsea a high grade of art tile is manufactured from a mixture of Pennsylvania kaolin, New Jersey clay, and Massachusetts quartz. Fireproofing is produced from common clay at Revere, and terra cotta at Clayton in part from a residual clay.

Potteries are located at about 18 localities. The product is chiefly earthenware, but some stoneware is also turned out. The Grueby fayence made at Boston is a unique type of pottery which has won considerable reputation.

The value of clay products in 1900 and 1901 in Massachusetts was as follows:

Value of clay products of Massachusetts in 1900 and 1901.

	1900.	1901.
Common brick	$1,123,586	$1,060,493
Front brick	87,575	98,892
Fancy brick	(a)	(a)
Fire brick	69,400	57,945
Stove linings	144,044	135,570
Terra cotta	(a)	(a)
Fireproofing	(a)	(a)
Tile (not drain)	(a)	(a)
Pottery	238,724	281,368
Miscellaneous	11,791	13,301
Total	1,833,101	1,870,837

a Less than three producers.

The total value of the clay products produced from 1895 to 1901 was as follows:

Value of clay products of Massachusetts from 1895 to 1901.

Year.	Rank.	Value.	Proportion of United States product.
			Per cent.
1895	8	$2,221,590	3.40
1896	8	2,264,974	3.63
1897	8	2,179,396	3.50
1898	9	1,809,070	2.48
1899	9	2,181,710	2.28
1900	10	1,833,101	1.91
1901	10	1,870,837	1.70

MICHIGAN.[a]

The clays of Michigan are derived from two types of deposits, (1) Paleozoic shales (Pl. IV), and (2) Pleistocene clays.

PALEOZOIC SHALES.

The formations yielding shales suitable for the manufacture of brick are those of the Coal Measures, the Michigan series, the Coldwater series, the Marshall shales, and the Hamilton or Traverse shales. The last two belong to the Devonian. The Hudson group also contains shales, but most of these are too calcareous to be used, although they could perhaps find application for the manufacture of Portland cement.

COAL MEASURE SHALES.

These occur interbedded with the coal seams and sandstones and are of three types, namely, a light-gray shale, often underlying the coal and erroneously called fire clay; a black fine-grained brittle shale; and a dark grayish-black shale. These last two usually overlie the coal seam. These shales are found associated with the coals in the different mines around Saginaw, Owosso, Corunna, St. Charles, Verne, Bay City, and Sebewaing. The sections at any two mines, although often but a short distance apart, may be quite different; but the following, taken from the shaft of the Standard Mining Company at Saginaw,[b] will illustrate the usual character of the Coal Measure sections.

[a] Most of the information regarding the clay industry in this State has been taken from the Report on the clays and shales of Michigan, by H. Ries: Michigan Geol. Survey, Vol. VIII, Pt. I.

[b] Ibid., p. 33.

Section at coal shaft near Saginaw, Mich.

	Feet.
Sandy clay	90
Fine-grained blue clay	10
Impure fire clay	3
Shale	8
Conglomerate	4
Black shale	20
Coal	--
Soft gray shale (called fire clay)	6

When ground up and mixed with water all of these shales give a plastic mass, but one whose tensile strength is usually low, as can be seen from the appended table (p. 156). Nevertheless they have in several places been found sufficiently plastic to be molded in stiff-mud brick machines for the mixing of paving brick or sewer pipe. They usually vitrify around cone 3 or 4 and become viscous anywhere from cone 5 to 11.

The Coal Measure shales form a basin lying southeast of Saginaw and having a diameter of about 50 miles. The outcrops are found chiefly around the edges of the basin, and in the center the shales are not only at a considerable depth below the surface, but there is usually a heavy covering of glacial drift or lake deposits at many points.

MICHIGAN SHALES.[a]

Rocks of this series form a belt from 10 to 20 miles wide surrounding the Coal Measure rocks in the Lower Peninsula. They are best exposed at Grand Rapids, where they form a bed from 6 to 10 feet thick, overlying the gypsum deposits. They are also seen in Huron and Arenac Counties, and along the Cass River in Tuscola County. From laboratory tests it is found that the Michigan shales are usually more fusible than those of the Coal Measures and that they burn to a good red color, although they may, in some cases, contain an abundance of soluble salts. Samples of them taken from weathered outcrops show considerable plasticity. These shales have been worked for the manufacture of brick at Grand Rapids.

COLDWATER SHALES.

The deposits of this series are very extensive and have been opened up in quarries at Bronson, Union City, and Coldwater. On the northeast side of the Coal Measures area they are well exposed near Forestville, on Lake Huron. Although hitherto used chiefly for the manufacture of Portland cement, the Coldwater shales will no doubt be found to be well suited for the manufacture of clay products. Samples tested show that they vitrify at about cone 2 and becomes viscous at cone 5.

[a] A geologic map showing distribution of the different formations is given in Water-Supply and Irrigation Paper No. 30, U. S. Geol. Survey.

MARSHALL SHALES.

The shales of the Marshall series of the Devonian are very extensive and are well developed around East Jordan, while the mellowed outcrops form a very tenacious clay and are used in the manufacture of brick. Like the Coldwater shales, they contain considerable soluble salts.

HAMILTON SHALES.

These outcrop around Alpena, but have not been used in the manufacture of clay products. Their chemical composition seems to show that they may be promising.

The search for shale outcrops in Michigan is often attended with difficulty, owing to the heavy covering of drift. In the central part of the Michigan coal basin the drift is very thick, so that prospecting is best carried on around its edges.

The coal shafts at Saginaw, Bay City, and other localities all afford an excellent opportunity for examining the shale beds.

ANALYSES AND PHYSICAL TESTS OF PALEOZOIC SHALES.

In the two following tables there are given the physical tests and chemical composition of a number of Michigan shale samples:

Analyses of Michigan shales.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
SiO_2	55.30	57.10	52.45	44.30	57.20	58.70	56.50	62.10	53.44	58.70	55.95	58.60	61.09
Al_2O_3	14.20	20.02	23.27	23.72	18.95	25.95	19.31	20.09	24.80	18.31	17.43	17.66	19.19
Fe_2O_3	3.62	8.18	7.93	7.68	8.31	.....	5.89	7.81	.....	7.19	7.67	7.44	6.78
$CaCO_3$	.30	.71	1.82	.....	.....	.....	1.00	.....	.....	1.80	2.14	2.14	.....
CaO	.....	.....	.....	1.11	.83	1.00	.....	.65	.76	.....	.....	.....	2.51
$MgCO_3$	2.61	1.47	1.06	.....	.....	.....	1.85	.....	.....	.98	1.55	2.19	.....
MgO	.....	.....	.....	1.50	1.83	.74	.....	.96	.25	.....	.....	.....	.65
Alk	2.15	2.76	4.37	2.00	2.70	5.54	5.98	.....	.....	3.67	2.86	.....	3.16
H_2O	21.82	9.76	9.10	17.64	9.00	8.07	9.47	7.90	20.75	9.35	12.40	11.97	5.13
Org													
CO_2	.....	.....	.....	2.36	1.32	.....	.....	.....	.....	.....	.....	.....	.....
SO_3	.....	.....	.....	.....	.12	.....	.....	.49	.....	.....	.....	.....	1.42

1. Coal Measures clay under coal, Standard Mining Company, Saginaw. Michigan Geol. Survey, Vol. VIII, Pt. I, p. 26.

2. Upper layer of shale, underlying coal, Michigan Coal and Mining Company's shaft, Bay City. Ibid., p. 36.

3. Shale over coal, Wenona Coal Company, Bay City. Ibid.

4. Gray shale, Grand Ledge. Ibid., p. 38.

5. Black shale, same locality. Ibid.

6. Shale, Michigan series, Grand Rapids. Ibid., p. 40.

7. Shale, Michigan series, Alabastine quarry, Grand Rapids. Ibid., p. 41.

8. Coldwater series, Bronson. Ibid.

9. Coldwater series, Coldwater. Ibid., p. 43.

10. Same, Forestville. Ibid., p. 46.

11. Devonian shale, East Jordan. Ibid.

12. Devonian shale, East Jordan. Ibid.

13. Hamilton shale, Alpena. Ibid., p. 48.

Physical characters of Michigan shales.

Locality.	Per cent of water required for mixing.	Tensile strength.	Plasticity.	Air shrinkage.	Fire shrinkage.	Incipient fusion.	Vitrification.	Viscosity.	Color.	Michigan Geol. Survey, Vol. VIII, Pt. I.
						Cone.	*Cone.*	*Cone.*		*Page.*
Owosso, under clay	19	35–40	Low	4	5	02	4	9	Red	27
St. Charles	18		do	4	8	1	5	8	Gray, buff.	28
Flushing... Dark-gray shale	20	35–40	do	3	6	1	6	8	Deep red.	32
Flushing... Light-gray clay	20	60–65	Fair	5	7	1	7	11	Gray, buff.	31
Saginaw, Standard Mining Co., under clay.	20	55–65	do	4	6	1	4	9	Red	33
Bay City, Central Coal Mining Co., under clay.	20	50–60	do	5		1	5	11	Buff	35
Sebewaing, Michigan Standard Coal Co.	17	90	Good	5	8	1	5	9	do	37
Grand Rapids, Alabastine Co., quarry.	32	105	do	6	10	05	01	3	Red	40
Coldwater, somewhat weathered.	21	125–139	do	7	9	03	2	5	do	42
Quincy, fresh shale	19	75–80	Fair	4	8	03	3	6	Deep red.	42
White Rock	19	36–42	Low	4	7	03	3	6	do	44
Norwood	24	135–150	Good	6	8	02	1	3		46

PLEISTOCENE CLAYS.

These are divisible into three groups, namely, lake deposits, river deposits, and moraine deposits. All of these deposits are very calcareous except the river clays, which are least so, and these are rather gritty. In many cases the lake clays have been leached in their upper portions, and being thus freed from lime these beds nearer the surface tend to burn red. The lake clays are extensively developed around Detroit, Port Huron, South Haven, Marquette, Saginaw, and Escanaba. They are found often at a height as much as 50 or 60 feet above the present lake level. They are usually fine-grained, nearly always calcareous and fuse at a low temperature. Their tensile strength commonly ranges from 150 to 170 pounds per square inch. The moraine clays form irregular masses in the terminal moraine, and are worked at Ionia and at Lansing. Their physical properties are similar to those of the lake deposits. The river clays are less extensive. They are being worked to the north of Sebewaing.

No clays of a refractory nature have thus far been found in the State. At Rowlee, in Ontonagon County, there is found a very fine-grained calcareous clay which can be used for slip and pottery.

Analyses of Michigan surface clays.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
SiO_2	58.50	52.35	54.62	55.35	44.15	40.15	42.85	47.75	41.86	52.26	52.92	57.75
Al_2O_3	18.69	14.90	12.82	17.89	10.00	11.25	9.87	17.60	10.70	22.95	12.25	14.39
Fe_2O_3		5.60	2.00	6.86	4.08	4.88	3.43	9.13	5.02	8.15	6.45	4.41
$CaCO_3$		15.10		7.25	24.64	21.43	25.55	2.60	14.33		13.84	
CaO	11.46		13.68							4.48		7.18
$MgCO_3$		5.75		2.65	1.50	8.93	13.23	.70	2.81		3.55	
MgO	1.75		4.25							1.32		2.36
Alkalies		1.61	12.01	5.00	1.55	2.06	5.07	2.21	2.80		3.35	4.87
H_2O		3.95			12.13	9.25		22.01	8.00	10.56	7.14	
Org					1.95	2.05						9.60
CO_2	10.93								14.50			
SO_3		.34		.86								

1. Prairie Farm, junction of Flint and Shiawassee rivers. Michigan Geol. Surv., Vol. VIII, Pt. I, p. 49.
2. Grayling, Crawford County. Ibid.
3. Marquette, Marquette County. Ibid.
4. Middle Lake. Ibid.
5. Detroit, Wayne County, brick clay. Ibid., p. 53.
6. Detroit, Wayne County, pottery clay. Ibid.
7. Harrietta, Wexford. Ibid., p. 54.
8. Saginaw, at shaft of Standard Mining County. Ibid., p. 55.
9. Lansing, Ingham. Ibid., p. 59.
10. Jackson, Jackson County. Ibid., p. 60.
11. Rockland, Ontonagon, slip clay. Ibid., p. 61.
12. Rockland, Ontonagon, slip clay.

Physical tests of Michigan surface clays.

Locality.	Per cent of water required in mixing.	Tensile strength in pounds per square inch.	Air shrinkage.	Fire shrinkage.	Incipient fusion.	Vitrification.	Viscosity.	Color.	Page of report.	Plasticity.
Detroit, Clippert Bros., upper clay	24	150–190	4	11	01	2	4	Buff	50	Excellent.
Detroit, Clippert Bros., lower clay	26	175–190		15	05	1	5	Gray, red	50	Do.
Ionia Pottery clay	28	150–170	8½		05	2		Cream	51	
Brick clay, Ionia	18		6		05	2	4	Red buff	52	
Saginaw, over Standard Mining Co. section	33	105–110	7	11	05	01	3		55	
Kalamazoo, 6 miles from	23	135–150	6	11	04	2	4	Red	56	

CLAY-WORKING INDUSTRY.

The clay-working industry of Michigan is confined chiefly to the lower grades of clay products. Common brick are made in considerable quantities from the calcareous surface clays at many localities, especially around Detroit, Port Huron, Lansing, etc. They are often of a buff color, but are sometimes red, especially when the

leached surface beds are used. In most cases the market for the product is chiefly local. Paving brick are manufactured from the Carboniferous shales in the vicinity of Saginaw and Bay City, and sewer pipe are made at Grand Ledge, from shales of the same age. Though there is a considerable quantity of shale in the State which is available for the manufacture of clay products, such as paving brick, still the development of these branches of industry will probably be slow, owing to the conditions that exist in that region. Located as Michigan is, right next to the State of Ohio, which has enormous deposits of shale and clay that can be worked with the greatest ease and economy, it would be difficult for Michigan manufacturers to compete, even within the boundaries of their own State, with the Ohio products. The glacial clays at Ionia are used in the manufacture of earthenware, especially flowerpots and jugs.

The value of the clay products in Michigan in 1900 and 1901 was as follows:

Value of clay products of Michigan in 1900 and 1901.

	1900.	1901.
Common brick	$863,250	$1,095,254
Pressed brick	48,411	64,031
Vitrified brick	(a)	(a)
Fancy brick	4,500	(a)
Drain tile	114,747	98,972
Sewer pipe	57,916	(a)
Fireproofing	2,350	1,880
Earthenware and stoneware	34,317	42,465
Miscellaneous	406	637
Total	1,181,695	1,542,034

a Less than three producers.

The total value of the clay products of Michigan for several years past has been as follows:

Value of clay products of Michigan from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$1,129,195	11	1.73
1896	1,005,405	12	1.61
1897	791,870	19	1.27
1898	1,018,312	14	1.42
1899	1,283,997	15	1.34
1900	1,181,695	18	1.23
1901	1,542,034	17	1.40

MISSISSIPPI.

The clay deposits of this State are all obtained from recent formations. The Cretaceous beds occupy the northeastern corner of the State, being a continuation of the Alabama area.

The following notes are given by Dr. Hilgard in his Report on the Agriculture and Geology of the State of Mississippi, 1860, regarding the clays in townships 4, 5, and 6, in Tishomingo County:[a]

"A large deposit of white pipe clay of great purity . . . occurs in Tishomingo County, chiefly in the southern portion of the territory of the Carboniferous formation, following very nearly its western outline. It there forms a regular stratum of considerable extent, which, in one locality at least, was found to be more than 30 feet in thickness. The bed attains its best development, so far as the quality of the material is concerned, in the northern portion of township 5, and in T. 4, R. 11 E., where it is about 30 feet underground in the uplands, though at times appearing in limited outcrops on banks of the streams. Northeastward and southwestward from the region mentioned the bed also occurs, but changed in character, at least near the surface, to a white, gritty hardpan, or clays of various colors and of much less purity. It forms the lowest visible portion of the Orange Sand formation, and is almost invariably overlaid by strata of pebbles and puddingstone, which in their turn are sometimes overlaid by common orange-colored sand.

"The most southerly exposure of these beds known to me occurs on a small branch of McDouglas Mill Creek, on secs. 4 and 9, T. 6, R. 10 E., near Mr. Pannel's place. For more than a mile along this branch there are exposures in which about 20 feet of a whitish mass, varying from fine, clayey sand to a white, plastic clay, appears overlaid by thick beds (20 to 40 feet) of ferruginous pebble conglomerate, the latter in its turn being overlaid by the common ferruginous sand and brown sandstone on the hilltops.

"Similar outcrops appear in the neighborhood of Mr. Aleck Peden's place on secs. 3 and 27, T. 5, R. 10 E., northeast of Pannel's. Here also a white stratum, of which only a few feet are exhibited, is overlaid by pebble conglomerate, and this by the common Orange Sand. The white mass varies from white, plastic clay to fine-grained aluminous sandstone. Its upper layers are sometimes composed of a singular conglomeratic mass, consisting of small, white, quartz pebbles imbedded in pure white pipe clay. In both localities copious springs of pure water are shed by the impervious clay strata. At Mr. Peden's there is a fine, bold, chalybeate spring, which seems, however, to derive its mineral ingredients (sulphates of iron and magnesia and common salt) from the adjacent Carboniferous strata rather than from those of the Orange Sand. In either of the localities mentioned, materials suited for fine pottery, or queensware, might be obtained.

"Thence northward the stratum is not often found outcropping, but [lies], as has been stated, 20 to 30 feet below the surface of the uplands, the country being but slightly undulating. At Mr. Clingscale's, sec. 8, T. 5, R. 11 E., the clay stratum was struck at the depth of about 30 feet beneath sand and pebbles; it was dug into

[a] Op. cit., pp. 34–36.

without being passed through, for nearly 30 feet more, no water being obtained from below, but dripping in above from the base of the pervious strata. The whiteness and plasticity of the material seemed to increase with the depth. The best portions of what was dug out of the well had already been removed at the time of my visit, having been used for various economical purposes, as 'chalk,' whitewash, and 'Lily White.' The specimens examined were, therefore, rather below the average quality, and on long exposure to the air their surface shows some yellowish spots. I found, nevertheless, that in baking at a high heat they yielded a biscuit of greater whiteness than their natural color when fresh, and that fine splinters exposed for ten minutes to the highest heat of the mouth blowpipe retained their shape perfectly while reduced to a semitransparent grit. A quantitative analysis of the clay from Clingscale's well gave the following results:

White pipe clay from Clingscale's.

	Per cent.
Insoluble matter	90.877
Lime	.140
Magnesia	Trace.
Peroxid of iron	.126
Alumina	2.214
Water	6.930
Total	99.864

"This analysis (which was made solely for the purpose of ascertaining the ingredients foreign to the clay proper) proves the singular fact that this clay, though occurring in a formation characterized by the large amount of iron it commonly bears, contains a remarkably small amount of that substance, which, together with minute proportions of lime and magnesia, explains its infusibility."

The usual section seen in the clay pits involves Lafayette red sands which seem to overlie unconformably the beds of stoneware clay and white sands.

Several potteries are located at Holly Springs, at which locality two different clay pits are extensively worked. The section, according to E. C. Eckel, is as follows:

Section at Holly Springs, Miss.

	Feet.
Clay and sandy soil	3
Alternations in 2 to 4 inch bands of yellow sand and clay	3
Gray clay	6

The eastern pits of this company show about 20 feet of clay, with much interbedding of white and yellow sands.

Harper, in his report on the Geology and Agriculture of the State of Mississippi (1857), refers to white clay[a] occurring in sec. 14, T. 7, R. 6 W., in Wayne County. Pottery clay is mentioned from near Woodville, sec. 28, T. 2, R. 2 W., and also in Tippah County, sec. 17, T. 2, R. 3 E. All of these are plastic. Clays similar to those found at Holly Springs are said to occur in Panola County, sec. 18, T. 8, R. 8,[b]

[a] Op. cit., p. 169.

[b] Ibid., p. 244.

and in Yazoo County, at the base of the hills crossing the county from north to south, and again in Calhoun County, near Hartford.

Pottery clay is also noted[a] in the bluff at Natchez, and at White Cliffs.

The value of the clay products produced in Mississippi in 1901 was as follows:

Value of clay products of Mississippi in 1901.

Common brick	$443,939
Front brick	$6,455
Pottery	$4,779
Rank	33
Per cent of United States product	.41

NEW JERSEY.

The various geologic formations extend across the State in a general northeast-southwest direction, their areas being somewhat as follows:

A band of pre-Cambrian gneisses, limestones, and schists enters the State on the northern border, having a width of about 20 miles and covering eastern Sussex, western Passaic, portions of Morris, Hunterdon, and Warren counties. It narrows considerably southward, and is interbelted with areas of limestone, leaving the State at Riegelsville and Easton. Northwest of this area, in western Sussex and Warren counties, are strips of Hudson shales and Trenton limestones, while along the west border of the State, from the Water Gap to Port Jervis, are narrow belts of Medina sandstone, Onondaga (Corniferous) limestone, and Marcellus shale.

The Triassic or Newark group forms a belt lying southeast of the pre-Cambrian rocks, its southeastern limit being the Hudson River, Arthur Kill, and thence southwestward through Bonhamtown, Milltown, Monmouth, Port Mercer, and Trenton, where it leaves the State. Its western edge extends from west of Mahwah, Bergen County, to Morristown, then through Bernardsville, Peapack, Lebanon, Juttland, Pattenburg, and Holland. The Triassic consists of sandstones and shales with intrusions of diabase.

The Lower Cretaceous forms a straight and even belt, 7 miles wide at South Amboy and 5 at Trenton, and then continues as a narrow irregular band from Kinkora to opposite Philadelphia, and beyond that as isolated patches. The Upper Cretaceous forms a broader belt, whose border passes through Long Branch, Prospectown, New Egypt, New Lisbon, Clementon, Hurffville, East Lake, and Salem. Between this line and the coast the surface is underlain by Tertiary and later deposits, but the latter may also cover the Cretaceous in places.

The terminal moraine marking the southern limit of the glacial drift extends from Perth Amboy in an irregular line to Danville, and then westward to Belvidere.

[a] Wailes, B. L. C., Agriculture and Geology of Mississippi, 1854, p. 228.

The character and qualities of the clay-bearing formations are summarized below.

HUDSON SHALES.

This is probably the only formation of the Paleozoic series which is likely to prove of value to the clay worker. The Hudson shales are found in a broad belt in Wantage, Frankford, Hampton, and Stillwater townships of Sussex County, and Hardwick, Blairstown, Knowlton, and Frelinghuysen townships of Warren County. In this area they are worked near Port Murray for the manufacture of fireproofing and bricks.

MARCELLUS SHALES.

The Marcellus shales form a narrow strip along the northwestern border from Tristates to Egypt Mills. They are of no value to the clay worker, for they contain too much sand and ferric oxide.

NEWARK GROUP.

The rocks of this group underlie a large area in the counties of Passaic, Union, Somerset, Hunterdon, and Mercer, and consist of sandstones, conglomerates, and shales, pierced by sheets and dikes of trap rock. The shales are found throughout the area, but predominate in the southwestern portion. Attempts have been made from time to time to develop the shaly beds, but with little success, as they lack plasticity and are of very low fusibility. It is of course possible to work them into bricks, but with the abundance of other and better clays in the State they are not likely to be utilized for some time at least.

CRETACEOUS.

This, the most important clay-bearing series found in New Jersey, forms a broad belt extending across the State from Raritan Bay and Sandy Hook to the Delaware River, Trenton marking its northwestern edge and Salem, in Salem County, its southeastern edge.

In New Jersey the Cretaceous is divisible into an upper and lower portion, and since the Cretaceous dips gently to the southeast, the Lower Cretaceous outcrops on the northwestern side of the Cretaceous belt.

LOWER CRETACEOUS.

The outcrops of these beds form a belt 4 to 5 miles wide, extending from Perth Amboy to Trenton, and thence farther southwestward along the Delaware River as a narrow irregular band. These beds formed the basis of a large report on the clays of New Jersey[a] by the late Professor Cook, and up to the present time this volume is practically the only published information concerning them.[b]

[a] New Jersey Geol. Survey, 1878.

[b] A new report covering the entire State is now in preparation by the New Jersey Geol. Survey.

From the study of the beds Professor Cook made the following sections:

Section of Lower Cretaceous rocks of New Jersey.

	Feet.
1. Dark-colored clay, with beds and laminæ of lignite	50
2. Sandy clay with sand, in alternate layers	40
3. Stoneware clay bed	30
4. Sand and sandy clay, with lignite near bottom	50
5. South Amboy fire-clay bed	20
6. Sandy clay, generally red or yellow	3
7. Sand and "kaolin"	10
8. Feldspar bed	5
9. Micaceous sand bed	20
10. Laminated clay and sand	30
11. Pipe clay, top white	10
12. Sandy clay, including leaf bed	5
13. Woodbridge fire-clay bed	20
14. Fire-sand bed	15
15. Raritan clay beds. Fire clay	15
Sandy clay	4
Potter's clay	20

Of this series several are very important and well marked, viz, the Stoneware clay 3, the "Kaolin" bed 7, the Woodbridge fire clay 13, and the Raritan clay 15. The beds all dip to the southeast, that of the Woodbridge being 51 feet per mile, of the South Amboy bed 48 feet, and the Stoneware 28 feet. While the section is fairly well differentiable, and the individual members are often traceable for considerable distances, still the subdivisions vary in thickness, a bed being sometimes 6 feet thick in one pit and 3 feet in an adjoining one but a few feet distant.

Among such a series of deposits a variety of clays is naturally to be looked for, and there are those which are used for fire brick, saggers, pressed brick, hollow brick, flue linings, white earthenware, terra cotta, gas retorts, floor tile, etc. The Raritan potter's clay, found at the base of the series, is often very plastic, but not refractory. The Raritan fire-clay bed contains much fine sand, but has greater fire-resisting power. The fire-sand bed is seen in numerous pits about Woodbridge and the Raritan River. It is a white sand with some gravel, and occasional bits of lignite. The Woodbridge fire clay is named from its occurrence around the town of that name, having been extensively worked here and also at other points from Eagleswood to Bonhamtown. It ranges from a few feet up to 40 in thickness, averaging 20, but in places has been eroded.[a] A good exposure is shown in Pl. V, *B*. Its character is that of a bluish-white refractory clay, the different layers varying in siliceousness, and therefore being separated in mining.

[a] Cook, op. cit., p. 50.

The laminated clays and sands are well developed about Woodbridge, but especially along the Raritan River. These were formerly looked on as useless overburden in the mining of fire clay, but they are now extensively used in the manufacture of hollow brick, conduits, and common brick—indeed the quarrying work is done on such a scale that steam shovels are employed. They consist of alternating layers of sand and sandy clay, with lignite, pyrite, and mica. Of the feldspar and kaolin beds, the former represent a decayed feldspathic gravel with quartz pebbles, while the so-called kaolin is a micaceous sand, containing white quartz and mica, and is therefore incorrectly named.

The South Amboy fire-clay bed is best developed on the south side of the Raritan River, and is similar to the Woodbridge clay in importance. Its average thickness is 8 feet.

The stoneware clay outcrops southeast of the Amboy fire-clay bed and averages 15 feet.

These Lower Cretaceous beds are the most important found in New Jersey. They are extensively worked around Woodbridge, Perth Amboy, South River, South Amboy, and Bonhamtown, while farther southward newer developments are found along the Delaware River. While the clays form the basis of an important local industry, large quantities of them are also shipped to neighboring States, including New York, Connecticut, Massachusetts, Pennsylvania, Maryland, and Ohio.

The following table gives the composition of the different Lower Cretaceous clays:

Analyses of New Jersey fire clays.

RARITAN FIRE-CLAY BED.

Locality.	Silica combined.	Silica free.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	Moisture.	Reference.[a]
W. B. Dixon, Woodbridge	31.12	28.81	26.95	1.24	.....	0.07	Tr.	Tr.	1.90	9.63	0.57	78
B. Ellison, south-southwest of Bonhamtown	17.90	57.35	15.50	1.20	.....	.....	0.17	.....	1.60	4.90	1.30	165

WOODBRIDGE FIRE-CLAY BED.

W. H. Berry, Woodbridge	40.50	6.40	35.90	1.10	.....	.....	0.28	0.16	1.30	12.80	1.50	82-84
Loughridge & Powers, Woodbridge	42.23	.50	39.53	.50	0.10	.....	.41	.08	1.40	13.59	1.21	90-92
Same, extra sandy, Woodbridge.	20.00	51.80	18.92	.88	.....	.....	.48	.....	{with Al_2O_3}	6.70	.50	93
A. Hall & Son, Woodbridge	42.05	5.70	35.83	.77	.....	0.11	.44	.....	1.10	12.20	1.50	94-96
H. Cutter & Sons, Woodbridge	43.90	1.10	38.24	.36	Tr.	.11	.15	.....	1.30	14.10	.70	105-109
W. H. P. Benton, Woodbridge	42.00	1.40	36.56	1.04	.....	.....	.35	.37	1.40	14.60	.80	114-115
Charles Anness & Son, Woodbridge	34.30	20.60	31.66	.74	.....	.....	1.53	.....	{with Al_2O_3}	10.50	.60	115-116
Crossman Clay and Manufacturing Co., Raritan River	37.85	10.50	35.75	.95	.....	.....	.37	.....	1.60	12.30	1.00	144-146
R. N. & H. Valentine, Sand Hills.	39.80	8.10	36.34	1.01	.....	.04	.15	.....	{with Al_2O_3}	12.90	1.20	153
C. A. Campbell & Co., Sand Hills, white fire clay	36.20	12.20	35.94	.96	.....	.....	.08	.....	1.50	12.10	1.10	150

[a] Figures given are pages for reference in Rept. New Jersey Geol. Survey on Clays, 1878.

Analyses of New Jersey fire clays—Continued.

SOUTH AMBOY FIRE-CLAY BED.

Locality.	Silica combined.	Silica free.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	Moisture.	Reference.[a]
E. F. Roberts, pits near Eagleswood	40.40	5.20	38.40	1.20	0.22	0.25	0.59	.....	{with Al_2O_3}	12.50	1.30	135
E. F. & J. M. Roberts, pits near South Amboy	42.71	.70	39.24	.46	.20	.....	.47	0.42	1.60	13.32	1.58	200
Same, selected clay	44.20	.20	39.14	.45	.....	.....	.25	.....	1.05	14.05	.90	203
G. Such, Burts Creek, washed clay	42.90	1.50	38.34	.86	.....	.....	.26	.18	1.20	13.50	1.10	197
Sayre & Fisher, Sayreville	41.10	3.10	38.66	.74	.....	.....	.28	.18	1.20	13.55	1.00	188

FELDSPAR BED.

W. M. Weidner, Forbes farm, Perth Amboy township	16.85	58.40	18.80	0.49	.....	.....	0.15	0.21	{with Al_2O_3}	4.90	0.80	119
Edgar Bros., Woodbridge township	16.50	57.10	17.46	.54	.....	.....	.12	.21	.90	6.30	.50	137
Knickerbocker Life Insurance farm, Perth Amboy township	77.40		16.07	.53	.....	0.25	.15	.....	.....	4.30	.....	125

"KAOLIN" BED.

Merritt's, Perth Amboy township	77.10		17.10	.....	.....	.....	1.30	.....	.....	4.50		129
Whitehead estate, Washington	89.40		7.80	.....	.....	.....	.....	.....	.....	2.60		178

FIRE SANDS.

A. Hall & Sons	96.30		3.15	.....	.....	.....	.....	.....	.....	.....	.....	.....
A. Hall & Sons	92.50		6.65	.....	.....	.....	.....	.....	.....	.....	.....	.....
M. Compton's, SE. of Bonhamtown	98.00		1.45	.....	Tr.	.....	0.20	Tr.	0.25	.....	.....	159
M. Compton	96.40		2.10	.....	.....	.....	.....	.....	.....	.....	.....	.....

[a] Figures given are pages for reference in Rept. New Jersey Geol. Survey on Clays, 1878.

UPPER CRETACEOUS.

The Upper Cretaceous is of less importance than the Lower Cretaceous. It is composed of a series of sands, clays, and greensand marls, forming a belt lying to the southeast of the Lower Cretaceous zone of outcrop. The following classification is made by W. B. Clark:[a]

Upper Cretaceous
- Manasquan formation.
- Rancocas formation.
- Monmouth formation.
- Matawan formation.

The lower of these, the Matawan, is the only one of importance to the clay worker. It contains beds of sand and clay, the latter being generally black or drab and sometimes calcareous.

This formation occurs typically on Matawan Creek, in Monmouth County. In its lower part are a series of clays, known as the Crosswick clays from their occurrence at Crosswick village, on Crosswick Creek, Burlington County. The clays are

[a] Ann. Rept. New Jersey Geol. Survey 1897, p. 174.

plastic and in their lower beds many carry pyrite. They are well exposed on the shores of Raritan Bay[a] and in the valleys of Matchaponix Creek, Crosswick Creek, Black Creek, and other tributaries of the Delaware River. To the south these clays pass into sands.

The Crosswick clays have been extensively used for brickmaking along Matawan Creek, Monmouth County; on Crosswick Creek and near Bordentown and Kinkora, in northern Burlington County; on Pensauken Creek near Senola, east of Camden, Camden County; and at Woodbury, in Gloucester County.[b]

TERTIARY AND PLEISTOCENE CLAYS.

These form scattered areas lying southeast of the Lower Cretaceous belt. They do not form continuous beds, but are irregular in form, with a tendency toward a basin-shaped structure. Their exact vertical or horizontal distribution has not yet been worked out. The formations recognized are the Bridgeton (Lafayette), Pensauken (Columbia), and Cape May. They contain many beds of clay, often of high plasticity and tensile strength. Some of the deposits are buff burning and semirefractory, and will no doubt serve as an important basis for the future development of New Jersey's already extensive clay-working industry.

North of the terminal moraine are many small deposits of glacial clay, which are found chiefly in the valleys and often afford an excellent brick-making material. These clays may also be found in the terminal moraine as well. To the south of the latter alluvial clays are not lacking in the valleys, but here they are usually the wash from the residual clays formed on the neighboring hillsides.

CLAY-WORKING INDUSTRY.

New Jersey now ranks fifth among the clay-producing States, as may be seen from the following table:

Value of clay products of New Jersey from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$4,899,120	5	7.50
1896	4,728,003	5	7.58
1897	6,180,847	3	9.91
1898	8,706,357	3	12.01
1899	10,787,273	3	11.26
1900	10,928,423	3	11.36
1901	11,681,878	3	10.60

[a] Ann. Rept. New Jersey Geol. Survey, 1897, p. 178. [b] Ibid., p. 208.

This position of importance among the States supporting a clay-working industry is due partly to the presence of many good clays and partly to the proximity to the important eastern markets, viz, New York, Philadelphia, and Boston. Furthermore, the location of many of the factories along tide water permits of the cheap shipment of the product. This applies to all grades of ware.

The value of the different grades of clay products made in New Jersey in 1900 and 1901 was as follows:

Value of clay products of New Jersey in 1900 and 1901.

	1900.	1901.
Common brick	$1,809,906	$1,675,406
Pressed brick	426,692	473,138
Vitrified brick	(a)	(a)
Fire brick	1,072,535	780,327
Drain tile	55,655	22,612
Sewer pipe	154,481	(a)
Terra cotta	647,884	920,644
Fireproofing	873,706	610,864
Fancy brick	4,112	11,514
Stove linings	(a)	(a)
Tile (not drain)	508,392	486,122
Miscellaneous	286,424	458,316
Plain red earthenware	28,600	21,489
Plain stoneware	46,650	60,000
Yellow ware	(a)	(a)
Plain C. C. ware	345,249	293,455
Plain white granite and semiporcelain	494,282	718,613
Semivitreous, incl. N. H	96,447	60,321
Total plain	3,820,948	4,361,127
Decorated C. C. ware	199,000	150,000
Decorated white granite	645,338	767,650
Decorated semivitreous	292,479	(a)
Total decorated	1,431,703	1,538,946
China (plain)	345,112	344,224
China (decorated)	(a)	321,724
Bone, delft, and belleek (plain)	38,800	237,835
Bone, delft, and belleek (decorated)	(a)	----------
Sanitary (plain)	1,807,953	2,194,354
Sanitary (decorated)	(a)	----------
Porcelain electrical supplies	285,466	342,479
Miscellaneous	325,389	88,357

a Less than three producers.

Common brick are made at many points, especially in the vicinity of the larger towns; but the region around Hackensack is the most important, for the extensive beds of Columbia clays found there are actively worked, supplying the market of New York City. Many common brick are also made from the Cretaceous clays around South River. In 1900 New Jersey ranked third as a producer of pressed brick, being outranked by Pennsylvania and Ohio. Large quantities of this product are made from the buff-burning fire clays of the Cretaceous belt near Perth Amboy, Sayreville, Trenton, etc. Hydraulic pressed brick are produced from Pleistocene clays at Winslow Junction and Mays Landing. Very few vitrified brick are made in New Jersey, chiefly because the raw materials are absent.

Terra cotta forms one of the important clay products of the State. In fact, New Jersey has been the leading producer of terra cotta for several years until 1900, when she fell slightly behind New York. Still, most of the terra cotta manufactured in the latter State is made from New Jersey clays. The terra-cotta factories are located chiefly in the Cretaceous clay belt, especially around Perth Amboy, the raw materials being drawn from various clay mines in that region.

Fireproofing is manufactured in enormous quantities, the production of New Jersey far exceeding that of other States, and forming about 47 per cent of the United States production in 1900. The ware finds a ready market in the Eastern cities. The industry is based chiefly on the impure sandy clays outcropping along the Raritan River, near Perth Amboy, and also on the Hudson shales at Belvidere. In the former district conduit pipes are also manufactured in large amounts from similar clays.

Sewer pipe were made in considerable quantities in New Jersey in former years, but the industry has declined, for the clays available are much less suitable for this purpose than those found in other States.

Glazed tile for interior decoration and floor tile of different solid colors are manufactured at Trenton and also Perth Amboy, but the raw materials are mostly imported from other States.

Fire brick and pottery are the two most important branches of the New Jersey clay-working industry. The fire brick of New Jersey have long held a high reputation, and the clays around Woodbridge are extensively wrought for this purpose. The shapes include ordinary brick, cupola brick, locomotive blocks, tuyere nozzles, and many special shapes. Most of these are made from a mixture of several clays, and the product not uncommonly shows a high percentage of silica. The following analyses were made some years ago by the Pennsylvania geological survey:

Analyses of fire brick made at Woodbridge, N. J.

	1.	2.
SiO_2	71.55	58.75
Al_2O_3	25.090	36.79
Fe_2O_3	1.280	1.39
TiO_2	1.05	1.75
CaO	.65	.11
MgO	.364	.301
Alkalies	.384	.913

1. Hall & Sons, No. 1 fire brick. Second Pennsylvania Geol. Survey, Rept. MM, p. 269.
2. Hyzer & Lewellen. Made from Woodbridge clay. Ibid.

A series of fire tests carried out by Prof. J. C. Smock showed that the bricks compared very favorably in refractoriness with those from other States.

Trenton is one of the two great pottery centers of the United States, the other being East Liverpool, Ohio. The location of factories at this point is due rather to its being a central point for shipment than to proximity of raw materials. The chief product is C. C. ware and white granite ware, but belleek, electrical supplies, vitreous china, and delft are made in smaller quantities. In recent years the manufacture of sanitary ware has been developed to an enormous extent. Fire brick, saggar clay, wad clay, and some ball clay are practically all that the white-ware manufacturer at Trenton draws from New Jersey. Most of the ball clay, and all of the kaolin, feldspar, and quartz are brought from other States, and even from England.

In addition to the factories located at Trenton, there are several others, situated at various points, as can be seen by reference to the map, Pl. IX.

Common earthenware, stoneware, and yellow ware are produced at Trenton and other localities.

CLAY-MINING INDUSTRY.

Much of the clay mined in New Jersey is shipped to other States, to be there worked up into refractory and other products.

The production of clay in 1900 and 1901 was as follows:

Production of clay in New Jersey in 1900 and 1901.

Material.	1900.		1901.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Kaolin (so-called)	2,986	$2,456	3,541	$4,040
Ball clay (raw)	(a)		(a)	
Ball clay (washed)	(a)		(a)	
Fire clay (raw)	210,635	272,707	225,424	328,370
Fire clay (washed)	(a)	(a)	16,023	63,579
Stoneware clay	16,621	29,189	26,538	46,290
Pipe clay	8,705	6,812		
Terra-cotta clay	38,123	43,687		
Miscellaneous	25,704	41,562	116,170	135,418
Total	321,219	467,881	392,946	594,894

a Less than three producers.

NEW YORK.

The greater portion of New York State is underlain by sedimentary rocks of Paleozoic age, ranging from the Cambrian to the Carboniferous, inclusive. These consist in very large part of shales, but sandstones and limestones are at times prominent. In the northeastern and southeastern portions of the State are two great areas of crystalline rocks, forming the Adirondacks and Highlands. The rocks composing them are anorthosites, granites, gneisses, and schists, which would yield clays only by their decomposition. The Cretaceous and Tertiary formations, so abundant in States farther south, are found in New York only on Staten Island, Long Island, and Fishers Island.

Overlying all of the above are deposits of Pleistocene age, composed of either glacial drift or of sediments deposited by streams flowing from the ice sheet during its retreat across the State.

The clay deposits of the State may be grouped as follows: (1) Residual clays, (2) Paleozoic shales, (3) Cretaceous and Tertiary clays, (4) Pleistocene clays.

RESIDUAL CLAYS.

Owing to the location of New York State north of the southern limit reached by the continental ice sheet during the Glacial epoch, very little of the residual clay which was formed by the surface decay of the rocks in pre-Glacial time has been left.

Some small deposits of kaolin are known to occur southeast of Sharon station and southeast of Fishkill Village, near Shenandoah Corners. Residual clay of more

or less ferruginous character is found in the limonite deposits at Amenia, Dutchess County, and small deposits have also been noted near Morrisania, where they have resulted from the decay of the dolomitic limestone.[a] None of these deposits have, however, proved of much commercial value. It is possible, though, that some kaolin beds of workable size may be found east or southeast of Sharon station, for a large one has been developed just east of the boundary line in Connecticut. If the material exists, it is to be looked for in the gneissic or schistose rocks.

The mellowed outcrops of some of the Paleozoic shales can perhaps be classed as residual deposits, but they differ from those mentioned above in being the results of disintegration and not of decomposition.

PALEOZOIC SHALES.

These may be developed into one of the most important clay resources of the State. Those found in New York State belong to the following formations: Chemung, Portage, Hamilton, Salina, Niagara, Medina, Clinton, and Hudson. All of these shale formations, with the exception of the Hudson, form bands of variable width extending across the State in an east-west direction. Their distribution can best be seen by reference to the geologic map of New York, from which it will appear that the oldest formations outcrop toward the north, in belts running parallel to Lake Ontario. The formations have a gentle southward dip of 40 to 60 feet per mile, and in passing across the State from the lake shore southward the outcrops traversed will be successively younger.

Of the shale formations mentioned above, the Hudson has no economic value for the manufacture of clay products, for it lacks plasticity and is very siliceous. The Niagara also is both calcareous and siliceous.

The Medina shale is well developed at Lewiston, on the Niagara River,[b] and along the Genesee River. It is not utilized in this State, but gives good results for dry-pressed brick in Ontario.

The Clinton shales are about 30 feet thick in places, notably in eastern Wayne County, and 24 feet thick at Rochester, Monroe County, and Wolcott Furnace. They have not been used and are probably often calcareous.[c]

The Salina forms a belt extending from Syracuse westward. The shale is soft, weathers easily, and possesses good plasticity, but may be quite calcareous, although good wares are made from it. Good exposures occur at Warner, Onondaga county.

The Hamilton, though extending from the Hudson River to Lake Erie, shows considerable lithologic variation, ranging from a sandstone to a clay shale. The latter phase is more common in the western part of the area underlain by it. It is

[a] Martin, D. S., and Merrill, F. J. H.: Trans. New York Acad. Sci., Vol. IX, 1889, p. 45.
[b] Bull New York State Museum No. 35, p. 827.
[c] Ibid., p. 828.

worked at Cairo, Greene County, and Jewettville, Erie County, in one place for paving brick, in the other for dry-pressed brick.

Overlying the Hamilton is the Portage, which consists of a lower shaly member, the Cashaqua, a middle member of shales and sandstones, and an upper sandstone. The shale occurs along Cashaqua Creek, also along Seneca Lake and at Penn Yan, but becomes gritty east of this point. It is 33 feet thick along Lake Erie at Eighteenmile Creek, and 150 feet thick along the Genessee River. The shale is worked at Angola.

The Chemung includes the most southern shale formation of New York State, but it is interbedded with sandstones which become very prominent toward the east.

The section given by Professor Hall, beginning at the top, is as follows:

Section of Chemung formation in New York.

Sandstone and conglomerate.
Red sandstone.
Black, slaty shale.
Green shale with gray sandstones.
Gray and olive shales and shaly sandstones.
Olive shaly sandstones.

Specially good exposures occur on the Genesee River, and much shale is found westward from this point.

The following tables, compiled from Bull. New York State Museum No. 35, show the physical character and chemical composition of some of these shales.

Analyses of New York shales.

Locality.	Geologic age.	Uses.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Alkalies.	H_2O.	CO_2.	Miscellaneous.
Lewiston	Medina	Not worked	59.50	20.60	8.00	0.80	0.35	3.60	5.50	.....	.....
Rochester	Niagara	.....do	28.35	10.47	1.90	21.47	8.24	5.73	.....	.....	.....
Warner	Salina (calcareous layer in bank).	Paving, common, and hollow brick.	25.40	9.46	2.24	22.81	10.39	.95	[a]7.60	20.96	.....
Do	Salina red shale.	.....do	52.30	18.85	6.55	3.36	4.49	K_2O 4.65, Na_2O 1.35	[a]5.30	3.04	.....
Do	Salina blue shale.	.....do	57.79	16.15	5.20	2.73	4.67	K_2O 4.11, Na_2O 1.22	[a]4.50	3.42	.....
Windom	Hamilton	Not worked	57.30	21.61	6.50	2.52	1.50	.....	7.80	.....	.....
Do	.....do	.....do	61.15	14.57	7.20	3.06	.20	1.90	5.95	.....	.....
Angola	Portage	Flue linings	65.15	15.29	6.16	3.50	1.57	5.71	.....	.....	.....
Alfred Center	Chemung	Roofing tile	53.20	23.25	10.90	1.01	.62	2.69	6.39	.....	MnO_2 .52, TiO_2 .91, SO_3 .41
Hornellsville	.....do	Paving bricks	64.45	17.77	7.04	.58	1.85	K_2O 2.52, Na_2O 1.95	.....	.....	.....
Corning	.....do	Terra cotta	58.10	17.50	6.00	4.50	2.88	4.15	5.90	.....	.....

[a] Organic.

Physical tests of New York shales.

Locality.	Geologic age.	Uses.	Average tensile strength.	Incipient fusion.	Vitrification.	Viscosity.	Color.	Amount water required.	Plasticity.	Air shrinkage.	Fire shrinkage.
			Lbs. per sq. in.	*Cone.*				*Per ct.*		*Per ct.*	*Per ct.*
Lewiston	Medina	Not worked.	15	.04	1	4	Red	16	Lean	3	6
Windom	Hamilton	No. 2	40	.03	1	4	Red	22	Fair	4½	9½
Do	do	No. 3		.06	1	4	Red	20	Fair	2	6
Do	do	No. 4		.06	1			21		3	4
Do	do	No. 5	35	.03	1	5		19		3	
Angola	Portage		92	.06	01	4		21.4	Fair	4	10
Jamestown	Chemung		[a]45–69	.06	01	2		17	Lean	3	7
Alfred Center	do		61	.06	01	3		20	Moderate.	4	9
Hornellsville	do		[a]34–39	.06	01	4		20	Lean	2.7	5.8
Corning	do			.05	1	3–4		18	Lean	2	

[a] Range.

CRETACEOUS AND TERTIARY CLAYS.

These include the Cretaceous clays of the Coastal Plain region of Long, Staten, and Fishers islands, and some of possible Tertiary age in the same area. The clays of this region are of variable character, ranging from ferruginous ones to others that are low in impurities and are hence of refractory character. They are frequently siliceous, owing to the ever-changing conditions of deposition, and do not form beds of great extent, but on the contrary are often pockety or lens-shaped, the deposits of clay being surrounded by beds of sand, and the latter may thus often necessitate considerable stripping. Some of the deposits, as those at Glencove and Northport, have been worked for a number of years.

The Cretaceous age of many of these beds has been settled,[a] but those of supposed Tertiary age are still in doubt. On Long Island and Fishers Island the upper layers of the clay beds have been crumpled and shoved by the ice as it advanced southward from Connecticut.

The more important localities at which these clays are exposed are at Kreischerville, Staten Island; Glencove, West Neck, Oyster Bay, Little Neck near Northport, Wyandance, and Farmingdale, Long Island. Most of the Long Island localities are along the north shore, the clays outcropping in the bluffs. In the central portion and along the south shore of the island clays are rarely seen. The poorer grades are worked locally but the better ones are shipped.

[a] Bull. New York State Museum No. 35, p. 610 et seq.

The following table gives the composition of the clay of a number of the deposits:

Analyses of Cretaceous and Tertiary clays in New York State.

Locality.	Geologic age.	Uses.	SiO_2	Al_2O_3	Fe_2O_3	CaO.	MgO.	K_2O.	Na_2O.	Moisture.	H_2O.	Miscellaneous.	Reference.[a]
Elm Point, Long Island.	Cretaceous.	Terra cotta stoneware.	76.50	15.17	[a]1.34	.59	.11	.127	.81	.12	4.27	[b].07	818
Glencove (Mrs. McKenzie).	.....do.....	Stoneware..	55.30	29.90	1.10	Trace.	.65	2.50		.....	9.75	.....	820
Glencove (Carpenter's pit).	.....do.....	.....do.....	70.45	21.74	1.72	.24	.30	5.00		.....	.....	.....	820
White clay, Little Neck, near Northport.	.....do.....	.....do.....	68.34	19.89	[a].90	.35	Trace.	3.55	.84	.....	6.03	.....	821
Black clay, same locality.	.....do.....	.....do.....	58.84	23.40	[a]1.18	.....	.....	5.04	.34	.....	9.20	[c]1.03	821
White clay, Sea Cliff.	.....do.....	.....do.....	62.35	23.14	[a]1.12	.....	.....	3.17	1.76	.....	6.77	[c]1.09	821
Kreischerville (white clay).	.....do.....	Firebrick...	47.40	39.01	.15	Trace.	Trace.	Trace.	Trace.	.....	14.10	.....	789
East Williston, Long Island.	Pleistocene.	Common brick.	69.73	16.42	2.58	1.66	.69	6.27		.....	.....	.....	733
West Neck, Long Island.	(?)	.....do.....	61.01	19.23	5.43	.96	1.88	4.60		.....	.....	.....	735
Fishers Island..	(?)	.....do.....	53.77	20.49	9.23	2.04	4.22	9.60		.....	.....	.....	738
Farmingdale...	(?)	.....do.....	62.39	23.60	3.39	.70	.10	5.89		.....	.....	.....	739
Wyandance....	(?)	Pressed brick.	60.20	23.07	1.45	1.20	Trace	3.05		10.10		.....	742

[a] Figures given are pages for reference in Bull. New York State Museum No. 35. [b] P_2O_5. [c] SO_3.

These clays show as wide a variation physically as well as chemically, varying from easily fusible brick clays to semirefractory or even highly refractory ones. The physical characters of a few samples are summarized below.[a]

Physical tests of Long Island and Staten Island clays.

No.	Amount of water required to work up.	Plasticity.	Tensile strength.	Air shrinkage.	Fire shrinkage.	Incipient fusion.	Vitrification.	Viscosity.	Color when burned.
	Per cent.		*Lbs. per sq. in.*	*Per cent.*	*Per cent.*	*Cone.*			
1.....	34.7	Fair.....	20–25	6	8	.05	1	4	Red.
2.....	28	Good.....	30–40	8	7	.04	1	5	Do.
3.....	31	Fair.....	50–60	5	9	.03	2	5	Do.
4.....	33	.....do	40–50	6	10	.04	1	5	Do.
5.....	32.40	.....do	22–50	8	5	.....	8	27	Buff.
6.....	25	.....do	25–30	5.5	6.5	.....	7	27	Do.
7.....	38	.....do	11–14	10	8.7	.....	.....	35+	White.
8.....	31	.....do	20	6.5	8.5	.09	9	34+	Buff.

1. Upper clay, Meyer's brickyard, 2 miles north of Farmingdale, Long Island.
2. Lower clay, same locality.

[a] Bulletin New York State Museum No. 35.

3. Top sandy clay, Garden City Brick Company, Farmingdale, Long Island.

4. Mixture of middle and bottom clay, same locality.

5. Stoneware clay, Mrs. H. McKenzie's property, on north side of Mosquito Inlet at Glen cove, Long Island.

6. Yellow stoneware clay, Sammis pits, Little Neck, near Northport, Long Island.

7. White Cretaceous clay, Kreischerville, Staten Island.

8. Buff fire clay, Kreischerville, Staten Island.

PLEISTOCENE CLAYS.

They are divisible into four groups, viz, (1) morainal clays; (2) lacustrine clays, (3) local deposits formed in lakes; (4) estuary deposits.

The terminal moraine of the Glacial epoch crosses New York State in an irregular line, forming a series of irregular, hummocky hills, which often contain considerable clay. In most cases, however, the clay is either too stony or too sandy to be of economic value. In places, as at Newfield and other points in Tompkins County, these clays are comparatively free from stones, and can be worked for brickmaking. They are rather calcareous.

The lacustrine clays were laid down during post-Glacial time, when the waters of Lakes Erie and Ontario were dammed up to the north by the retreating continental glacier, and spread over the land in the western and northwestern part of the State, much clay being deposited during this time. These clays underlie the flats around Buffalo, Lancaster, Tonawanda, and other places in the northwestern portion of the State, and are used locally for brickmaking. They often contain lime pebbles and concretions, although the clays themselves are not very calcareous.

The lake deposits represent the most widely distributed source of brick clays found in New York State, since they occur in many of the flat-bottomed valleys, which have been filled up by fine clayey sediment deposited in local lakes. They may be calcareous, often contain beds of sand, and are of variable depth, being commonly underlain by hardpan. The extremes of depth are shown by the two following sections:

Section of Pleistocene clay at Rochester.

	Ft.	in.
Loam	1	6
Sandy clay	2	0
Fat clay	4	0
Hardpan	..	..

Section of Pleistocene clay at Jamestown.

	Ft.	in.
Yellow sand	4	0
Quicksand		6
Yellow clay	5	0
Blue clay	70	0
Hardpan	--	--

Most of these lake clays burn red and are used for common brick and fireproofing, though pressed brick and drain tile are sometimes made. Their areal extent may also vary. They are worked at a number of points, among which may be mentioned Rochester, Syracuse, Rome, Jamestown, Utica, Binghamton, Elmira, etc.

The estuarine clays are confined to the valleys of the Hudson River and Lake Champlain, and were formed during post-Glacial time, when the land stood at a lower level. There was then deposited a great mass of impure clays. Subsequent to this the land was elevated and still later these beds were cut down by streams, so that the remnants now form terraces along the sides of the valley. The deposits are of variable thickness, due to the irregular surface of the underlying bed rock and glacial drift. The section involves three members, viz, an upper sand, a yellow clay, and a blue clay. The clay bed is made of many thin layers separated by very thin laminæ of sand, and the deposit often shows a thickness of not less than 60 feet and in some instances over 200 feet. (Pl. VI.) The clays are easily fusible, red-burning materials, very constant in character from place to place. The physical test of one from Roseton illustrates well the physical nature.

Tests of clay from Roseton, N. Y.

Water required for working	per cent..	29
Tensile strength	pounds per square inch..	75–90
Air shrinkage	per cent..	5–6
Incipient fusion	cone..	.05
Vitrification	cone..	.04
Viscosity	cone..	.01
Fire shrinkage	per cent..	10

Though abundant in both the Hudson and Champlain valleys, those in the former are more extensively worked, but it is unfortunate that with the abundance and location of this material it is not adapted to the manufacture of other grades of product than common brick, drain tile, and common red earthenware. One exception is the deposit at Glens Falls, which is employed for terra cotta.

PLEISTOCENE CLAYS IN HUDSON RIVER VALLEY.

in two parts by a large horse of quartz. The analysis and physical characters are given in the table below.

In addition to this deposit there are others known—and in some cases worked—at Sylva, Jackson County; Bosticks Mills, Richmond County; Troy, Montgomery County; and Wests Mills, Macon County. Others, according to Dr. J. H. Pratt, are located 2 miles a little west of north of Bryson City, Swain County; another between this and Bryson City and 1 mile from the town; also 2 miles south of Hall station, Jackson County; and 2½ miles southwest at Canton, Haywood County.

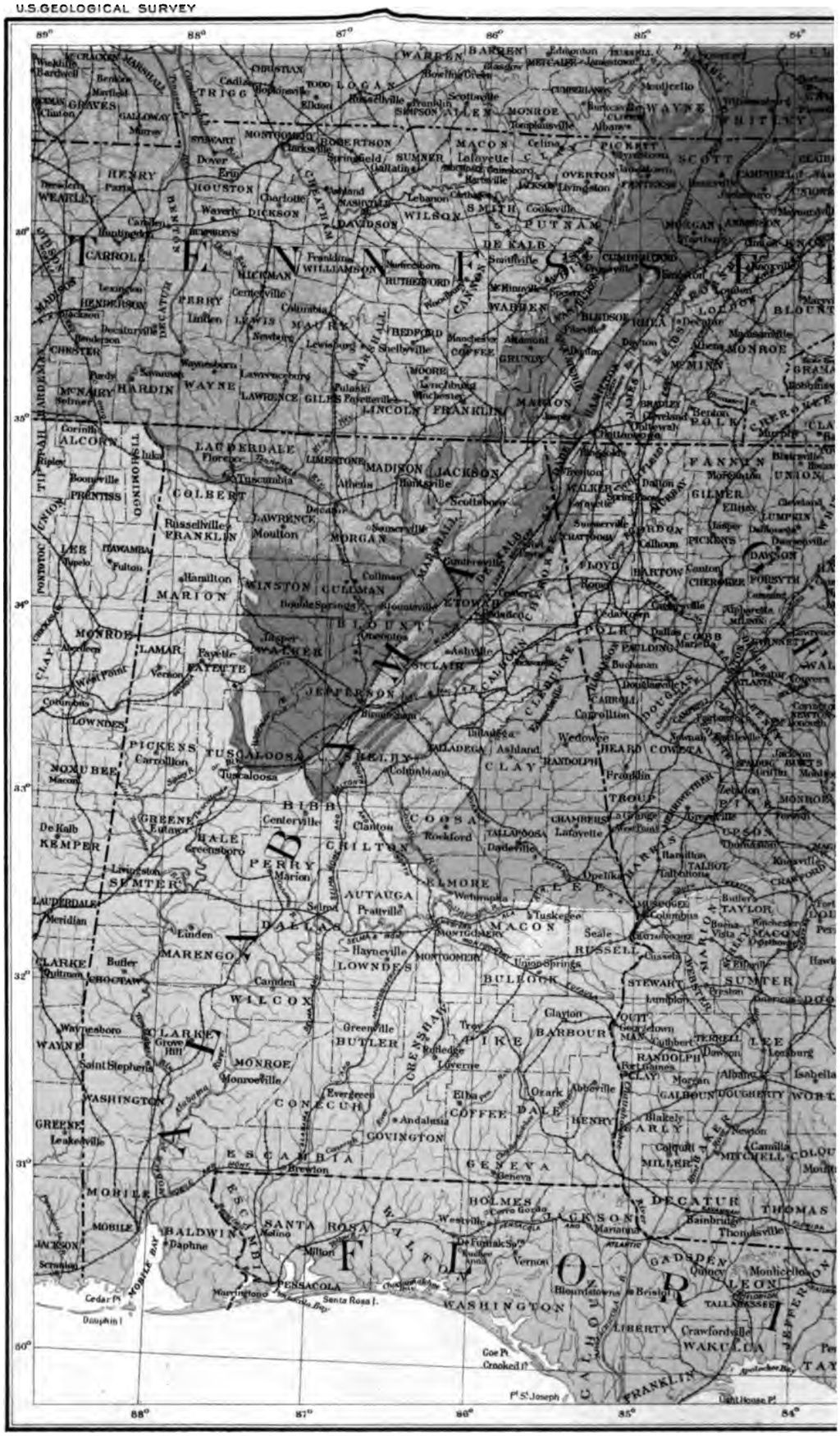
The chemical and physical properties of a number of residual clays from North Carolina are given herewith.

Chemical analyses of residual clays of North Carolina.[a]

Locality.	Moisture.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Alkalies.	H_2O loss on ignition.	Miscellaneous.	Total.	Clay substance.	Total fluxes.	Free sand.	Remarks.
CLEVELAND COUNTY.														
Eskridge pit, Grover	0.76	68.28	18.83	2.60	0.70	0.13	2.29	6.47	TiO_2, 0.27	100.33	46.99	5.72	53.30	Fire clay.
Powhatan Clay Manufacturing Co.'s pit, Grover.	1.29	53.07	29.54	1.27	.15	.14	$\{Na_2O–K_2O, .87–1.28\}$	9.93	FeO, 1.00	98.54	61.99	4.71	36.55	White pressed brick.
Same, one-half mile east of Grover.	.95	64.13	22.35	1.95	.10	.22	.99–1.81	5.98	.....	98.48	46.88	5.07	51.60	
GUILFORD COUNTY.														
Greensboro Brick and Tile Co.'s clay, Greensboro.	1.64	56.81	20.62	6.13	.65	.58	4.47	8.60	.....	99.5	58.85	11.83	40.65	Brick.
JACKSON COUNTY.														
Washed kaolin, Harris Clay Co., near Webster.	.35	45.70	40.61	1.39	.45	.09	2.82	8.98	.....	100.04	96.81	4.75	25.40	White ware.
Crude kaolin, Springer mine, near Webster.	.25	62.40	26.51	1.14	.57	.01	.98	8.80	.....	100.66	66.14	1.70	34.52	
Washed kaolin, Springer mine, near Webster.	2.05	45.78	36.46	.28	.50	.04	.25	13.40	FeO–1.08	99.84	93.24	2.15	6.60	
Washed kaolin, North Carolina Mining and Manufacturing Co., near Sylva.	3.07	44.08	36.26	1.86	.43	.20	.50	13.56	.....	99.96	94.21	2.99	5.75	Do.
MACON COUNTY.														
Crude kaolin, near Wests Mill, Brindel's land.	.....	53.10	33.06	1.18	.38	.08	.83	11.32	.....	99.95	83.39	2.47	16.56	
MONTGOMERY COUNTY.														
Dark kaolin, washed, 4 miles west of Troy.	.53	86.03	6.46	2.14	.17	.04	1.00	2.90	.....	99.27	20.83	3.35	78.54	
White kaolin, washed, 4 miles west of Troy.	.75	63.10	23.33	2.97	.15	.09	1.90	7.65	.....	99.94	58.92	5.11	41.08	
RICHMOND COUNTY.														
Kaolin, near Bosticks Mills.	.08	70.63	21.81	1.49	.20	.29	1.45	4.04	.....	99.99	47.14	3.43	52.86	Not worked.
Do.....	.17	68.15	19.99	1.86	.13	.16	2.85	4.70	.....	98.01	49.30	5.00	50.70	Do.
Do.....	.....	73.70	16.03	1.57	.38	.47	1.90	4.33	.....	98.38	36.05	4.32	62.33	Do.
R. L. Steele's pit, 4 miles north of Rockingham.	1.98	59.59	22.07	4.27	.65	.49	2.70	7.53	.....	99.28	51.63	8.11	47.65	Brick.

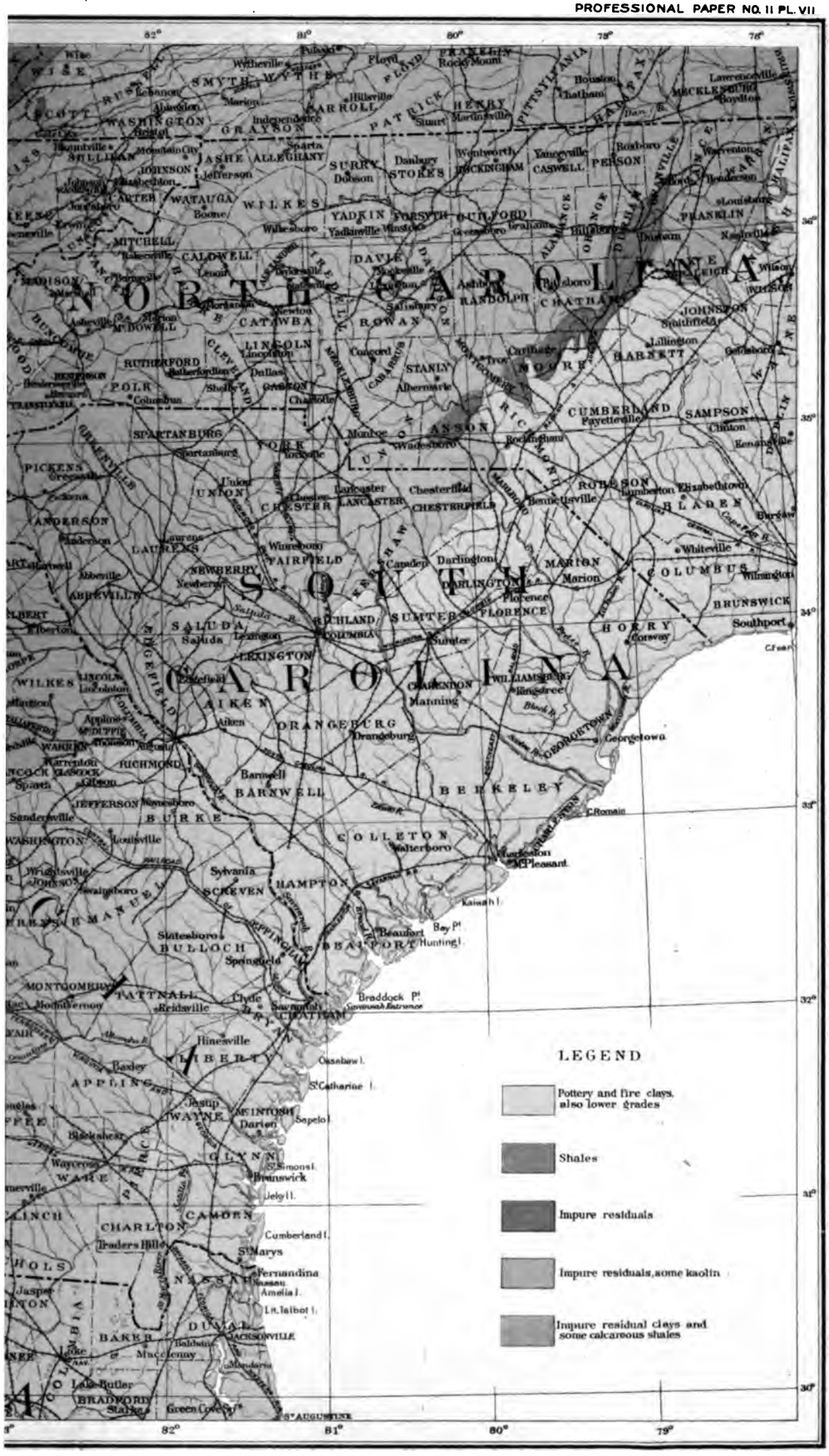
[a] Bull. North Carolina Geol. Survey No. 13.

U.S.GEOLOGICAL SURVEY



MAP SHOWING DISTRIBUTION OF CLAYS IN NORTH CAROLINA, SOUTH C.

25 0 25 50 75



GEORGIA, ALABAMA, TENNESSEE, AND PARTS OF ADJOINING STATES

Physical tests of residual clays from North Carolina.

Locality.	Percent H_2O added to give workable paste.	Plasticity.	Air shrinkage.	Fire shrinkage.	Total shrinkage.	Average tensile strength.	Maximum tensile strength.	Character of slaking.	Texture of clay.	Incipient fusion.	Vitrification.	Viscosity.	Total fluxes.	Color when burned.	Specific gravity.
			Per cent.	*Per cent.*	*Per cent.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*			° *F.*	° *F.*	° *F.*			
CLEVELAND COUNTY.															
Eskridge pit, Grover	32	Lean	10.6	6	16.6	38	42	Slow	Coarse to fine.	2,100	2,300	2,500	5.72	White to red.	2.57
Powhatan Clay Manufacturing Co. pit, southwest of Grover.	28	Good	8	5	13	39	45	....do	Fine	2,100	2,300	2,500	4.71	Whitish	2.24
Same, one-half mile east of Grover	31	Lean	4	4.5	8.5	31	35	Very slow.	Coarse	2,150	2,350	2,550	5.07	....do	2.51
JACKSON COUNTY.															
Washed kaolin, Harris Clay Co., near Webster	42	Lean	6	4	10	20	22	Slow	Very fine	2,300	2,500	2,700+	4.75	White	2.43
Crude kaolin, Springer mine, near Webster	32	...do	2	4	6	6	7	Fast	Coarse to fine.	2,300	2,500	2,700+	2.7	....do	2.58
Washed kaolin, Springer mine, near Webster	38	...do	8	4.5	12.5	23	24	Slow	Very fine	2,350	2,550	2,700+	2.15	....do	2.27
Washed kaolin, North Carolina Mining and Manufacturing Co., near Sylva.	40	...do	8	4	12	15	.....	....do	....do	2,200	2,450	2,700+	2.99	....do	2.31
MACON COUNTY.															
Crude kaolin, near Wests Mill, Brindel's land	31	Lean	6	6	12	15	18	Slow	Very fine	2,300	2,600	2,700+	2.47	White	2.31
MONTGOMERY COUNTY.															
Dark kaolin, washed, 4 miles west of Troy	30	Lean	3	10	13	9	12	Fast	Fine	2,100	2,300	2,500	3.35	Pale buff	2.32
Crude white kaolin, 4 miles west of Troy	28	...do	3	9	12	10	12	....do	....do	2,100	2,300	2,500	5.11	Yellowish white.	2.34
White kaolin, washed, 4 miles west of Troy	31	...do	3	6	9	11	14	....do	....do	2,100	2,300	2,550	.....	....do	.....
RICHMOND COUNTY.															
Kaolin, near Bostwicks Mills	27.7	Lean	4	9	13	10	14	Slow	Fine	2,250	2,500	2,700+	3.43	Yellowish white.	2.41
Do	26	...do	3.5	8	11.5	13	16	....do	....do	2,300	2,500	2,700+	5	....do	2.52
Do	27.7	...do	4	8	12	15	16	....do	....do	2,250	2,450	2,700+	4.32	....do	2.43
Washed kaolin, near Bostwicks Mills	26	...do	3	9	12	10	12	....do	....do	2,250	2,450	2,700+	.....	Yellow	.....
Do	29	...do	4	7	11	8	11	....do	....do	2,250	2,450	2,700+	.....	Light yellow.	.....
R. S. Steele, 4 miles north of Rockingham	26	Good	6	8	14	133	154	....do	Medium	2,000	2,200	2,400	8.11	Red	2.54

Chemical analyses of sedimentary clays of North Carolina—Continued.

Locality.	Moisture.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Alkalis.	H_2O Loss on ignition.	Miscellaneous.	Total.	Clay substance.	Total fluxes.	Free sand.	Remarks.
GUILFORD COUNTY—continued.														
Under pipe-clay, first pit, Pomona Terra Cotta Co	1.53	58.73	23.94	3.71	.05	.09	1.25	9.80	.....	99.10	65.70	5.10	33.40	Sewer pipe.
Upper pipe-clay, first pit, Pomona Terra Cotta Co	2.05	54.28	22.27	8.45	.45	.18	.60	10.50	[b] 1.33	100.11	67.57	11.01	32.51	Do.
Pipe clay, second pit, Pomona Terra Cotta Co	2.20	70.75	13.87	5.01	.82	.29	1.15	5.00	.....	99.09	39.40	7.27	59.70	Do.
Under fire-clay, Pomona Terra Cotta Co	1.17	70.15	15.51	3.34	.83	.07	3.75	5.14	.....	99.96	39.46	7.99	60.50	
Woodruff's fire-clay, 1 mile north of Pomona	1.43	71.60	15.27	3.33	.17	.21	2.12	5.40	.....	99.53	42.83	5.83	56.70	Fire brick.
HALIFAX COUNTY.														
Upper sandy clay, Roanoke Rapids	1.63	67.55	13.16	8.54	.17	.28	2.65	5.08	.....	99.06	41.98	11.64	57.08	Brick.
Middle clay, Roanoke Rapids	2.45	65.58	17.04	5.76	.72	.28	2.30	5.58	.....	99.71	56.70	9.06	31.50	Do.
Under clay, Roanoke Rapids	2.05	59.68	16.09	8.91	1.35	.14	3.24	6.33	.....	97.79	42.28	13.24	39.82	Do.
HARNETT COUNTY.														
Clay, C. F. & Y. V. R. R. 92-93-mile post, southeast of Spout Springs.	1.42	64.16	21.71	1.58	.23	.15	.77	8.30	[b] 1.08	99.40	58.55	3.81	40.90	Not worked.
Clay, C. F. & Y. V. R. R. 100-mile post, southeast of Spout Springs.	1.35	50.68	32.51	3.06	.30	.02	.58	11.08	.....	99.58	83.43	3.96	16.15	Do.
Clay, west of Spout Springs station	1.05	53.65	28.66	4.50	.10	1.35	.29	10.79	.....	100.39	73.77	6.24	26.65	Do.
JACKSON COUNTY.														
Brick clay, three-fourths mile south of Sylva	.45	66.70	19.75	3.25	.45	.16	2.12	6.65	.....	99.53	47.28	6.08	52.25	Do.
LINCOLN COUNTY.														
Pottery clay, T. Rhodes's place, 2 miles northwest of Lincolntown.	2.10	57.20	24.82	3.25	.73	.13	.93	8.25	[b] 1.42	98.83	62.27	6.46	36.57	Stoneware.
Same, 2¼ mile, northwest of Lincolntown	.69	57.08	26.11	4.64	.20	.16	1.42	8.52	.....	98.82	62.76	6.42	35.96	Do.
MECKLENBURG COUNTY.														
I. K. Cecil's yard, Charlotte	1.35	68.35	13.13	6.87	2.10	.32	2.82	5.20	.....	100.18	38.73	12.15	61.45	Brick.
F. W. Shuman's yard, Charlotte	7.10	59.15	18.36	6.04	.20	.34	1.72	7.47	.....	100.38	.....	8.30	39.50	Do.
F. M. Sassamon's yard, Charlotte	1.27	65.95	14.67	7.61	2.57	.25	2.55	5.52	.....	100.39	43.84	12.98	56.45	Do.
Upper clay, S. Asbury's yard, Charlotte	.63	60.33	18.57	10.03	.20	.14	.55	7.83	.....	98.28	56.23	10.92	42.05	Do.
ROWAN COUNTY.														
D. G. Cecil's pit, Salisbury	1.91	69.89	15.31	4.39	.55	.16	.70	6.37	.....	99.28	47.38	5.80	51.90	Brick.
ROBESON COUNTY.														
Clay, Red Springs	1.09	78.16	8.26	4.09	.40	.22	2.91	4.14	.....	99.27	15.22	7.62	74.05	Brick.
Pomona Sewer Pipe Co.'s pit, 1 mile west of Elkins [c]	.90	59.48	19.24	8.26	.60	1.01	3.76	6.41	.....	99.66	49.21	13.53	50.35	Not worked.

UNION COUNTY.													
J. T. Shute's pit, Monroe	1.65	76.60	9.98	4.46	.30	.27	2.25	4.30	.....	99.81	34.26	7.28	65.55	Brick.
WAKE COUNTY.													
Brick clay, penitentiary pits, Raleigh	1.60	70.03	15.64	2.88	.80	.57	1.47	6.37	.....	99.36	44.81	5.72	54.55	Brick.
WAYNE COUNTY.													
Brick clay, H. L. Grant's pit, Goldsboro	1.58	66.05	17.81	6.69	.30	.25	1.04	6.32	.....	100.04	51.47	7.76	48.05	Brick.
Clay, Weil's pit, Goldsboro	1.85	67.90	18.74	3.16	.40	.45	1.85	6.03	.....	100.38	46.23	5.86	54.15	Do.
Fire clay, H. L. Grant's pit, Goldsboro	1.12	65.95	13.51	4.64	.35	.36	2.82	11.58	.....	100.33	49.63	8.17	50.70	Not worked.
WILKES COUNTY.													
Pottery clay, just west of Wilkesboro	1.28	54.38	27.27	5.48	.45	.41	.68	9.78	.....	99.73	75.73	7.02	24.00	Stoneware.
Pottery clay, C. Cowles's pit, Wilkesboro	2.20	54.24	24.97	4.83	.57	.70	2.52	9.40	.....	99.43	67.08	8.62	32.35	Not worked.
Brick clay, D. Smoak's pit, Wilkesboro	1.03	53.75	24.91	7.99	.70	1.12	2.94	7.60	.....	100.04	34.04	12.75	46.00	Brick.
Bottom clay, D. Smoak's pit, Wilkesboro	2.10	52.25	20.66	11.14	.60	1.08	4.62	7.45	.....	99.90	57.45	17.44	42.45	Do.
WILSON COUNTY.													
Redtop clay, Lucas's south pit, northeast of Wilson	2.31	62.99	13.56	11.52	.10	.29	2.07	6.03	[b]0.33	99.20	55.90	14.31	43.25	Brick.
Blue clay, Lucas's north pit, northeast of Wilson	1.70	68.90	14.36	6.04	.03	.31	2.30	5.83	.....	99.47	46.72	8.68	51.75	Do.
Clay, Lucas's bank, east of Wilson	1.68	68.28	13.59	5.66	.15	.47	1.41	6.00	.....	97.24	43.69	7.69	53.55	

[a] Sulphur. [b] FeO [c] Surry County.

Physical tests of sedimentary clays from North Carolina—Continued.

Locality.	H_2O added to give workable paste.	Plasticity.	Airshrinkage.	Fire shrinkage	Total shrinkage.	Average tensile strength.	Maximum tensile strength.	Character of slaking.	Texture of clay.	Incipient fusion.	Vitrification.	Viscosity.	Total fluxes.	Color when burned.	Specific gravity.
	Per cent.		*Per cent.*	*Per cent.*	*Per cent.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*			°F.	°F.	°F.			
ROBESON COUNTY.															
Brick clay, Red Springs	17	Lean	8.8	4	12.8	41	51	Fast	Coarse	2,100	2,250	2,400	7.62	Red	2.60
ROWAN COUNTY.															
Brick clay, D. K. Cecil, Salisbury	28	Good	8.5	5.5	14	129	144	Slow	Fine	1,850	2,050	2,250	5.80	Red	
SURRY COUNTY.															
Pomona Sewer Pipe Co.'s pit, 1 mile northwest of Elkin.	16	Lean	7	9	16	69	73	Slow	Medium fine	1,900	2,100	2,300	13.53	Red	2.59
UNION COUNTY.															
J. T. Shute's pit, Monroe	23	Good	6	3	9	124	148	Slow	Medium	1,950	2,150	2,350	7.28	Red	
WAKE COUNTY.															
Brick clay, penitentiary pits, Raleigh	25	Good	9.3	4	13.3	123	144	Medium fast.	Medium	2,000	2,150	2,300	5.72	Red	2.54
WAYNE COUNTY.															
Brick clay, H. L. Grant's pit, Goldsboro	33	Fair	8	6	14	65	74	Medium fast.	Coarse to fine	1,900	2,100	2,300	7.76	Red	2.53
Clay, Weil's pits, Goldsboro	25	Good	8.3	3	11.3	85	102	Slow	Fine	1,900	2,100	2,300	5.86	Light red	2.57
Fire clay, H. L. Grant's pit, Goldsboro	25	do	8.5	5	13.5	107	125	Moderate fast.	do	1,950	2,150	2,300	8.17	Deep red	2.55
WILKES COUNTY.															
Pottery clay, just west of Wilksboro	40	Moderate	7	12	19.5	51	63	Slow	Fine	1,900	2,050	2,200	7.02	Red	2.37
Pottery clay, Calvin Cowles's property, one-half mile north of Wilkesboro.	35	Good	10		15	169	192	do	do	1,800	2,000	2,200	8.62	Gray brown	2.46
Brick clay, D. Smoak, Wilkesboro	25	Lean	5	10	15	74	76	Fast	do	1,900	2,100	2,300	12.75	Deep red	2.63
Do	24	do	6	9	15	71	84	do	Medium fine	1,900	2,100	2,300	17.44	do	2.44
WILSON COUNTY.															
Red-top clay, Lucas's S. pit, northeast of Wilson.	32	Lean	10	5	15	84	98	Fast	Medium	1,800	1,950	2,100	14.31	Red	2.62
Blue-top clay, Lucas's N. pit, northeast of Wilson.	30	Good	8	5	13.5	107	129	Slow	do	1,900	2,050	2,200	8.68	do	2.45
Blue-top clay, Lucas's bank, east of Wilson.	33	do		4	15	138	155	do	do	1,950	2,100	2,250	7.69	do	2.52

CLAY-WORKING INDUSTRY.

The most important product of North Carolina is washed kaolin, which is shipped to many potteries in the Northern and Central States. The most numerous class of clay works is that engaged in the manufacture of common brick, many yards being scattered over the eastern half of the State. Local centers are at Goldsboro, Fayetteville, Greensboro, Wilkesboro, Charlotte, and Raleigh. The clays used are mostly surface sediments, and in some instances residual.

Sewer pipe are made at Pomona from a mixture of clays dug in the valley of Buffalo Creek, and fire-brick factories are located at Enma, Buncombe County; Grover, Cleveland County; and Pomona, Guilford County. The clays used in each case are semirefractory and siliceous.

Stoneware is made at several small potteries in Catawba and Lincoln counties. Others are scattered over the State, as at Wilkesboro, Wilkes County, and 2 miles north of Morgantown, Burke County.

The potteries in Lincoln and Catawba counties obtain most of their clay from the lowlands along the Clarke River, north of Lincolnton, some of them having to haul it 15 miles. They pay 50 cents a ton for it. The methods of manufacture are very crude, and the glazes are usually a ground mixture of ashes and glass.

The following figures give the production of the different grades of ware for 1900 and 1901, and also the total production for the past several years:

Value of clay products in North Carolina in 1900 and 1901.

	1900.	1901.
Common brick	$737,577	$682,469
Front brick	4,025	8,070
Paving brick	(a)	.....
Fire brick	714	3,720
Stove linings	(a)	.....
Drain tile	7,186	5,042
Sewer pipe	(a)	.....
Miscellaneous	5,000	5,000
Red earthenware	1,937	2,015
Stoneware	16,498	17,470
Total	815,975	771,338

a Product made by less than three firms, and hence output not given.

extends across the State in a belt from Lake Erie to the Ohio River, through Erie, Huron, Seneca, Crawford, Wyandot, Marion, Morrow, Delaware, Franklin, Pickaway, Ross, Pike, and Adams counties. The beds dip eastward, so that the shale formations occur in the eastern half of the belt.

The shale formations are the Hamilton and the Ohio. The Hamilton has not been worked for clay products and does not seem likely to be, for there are few outcrops and its thickness is only from 15 to 20 feet. The Ohio shale, however, is said to have possibilities, being a great formation with many outcrops, and ranging between 250 and 400 feet in thickness. If followed eastward its thickness is found to increase to more than 2,500 feet, and its outcrops occupy a belt 10 to 25 miles wide that reaches entirely across the State from north to south. It is not a homogeneous formation, the beds varying considerably, but two leading types noticeable are a black shale and a greenish-blue shale. They are all highly siliceous, but the black shale has 8 to 10 per cent organic matter, and the greenish-blue variety owes its color to the silicate of iron which it contains. Columbus is practically the only point in the State where this series has been used. Here both sewer pipe and common brick are made of it. It was the greenish phase that was used in every case.

LOWER CARBONIFEROUS.

The Bedford shale is not always distinguishable from the preceding, and sometimes resembles it closely in color. In most places it is a red shale, and hence where it has this color can be easily identified. It is a very persistent bed, ranging from 20 to 80 feet thick. The Akron Vitrified Brick Company uses the red shale in making pressed brick, and it has also been mined and worked at or near Independence.

The Cuyahoga shale is a great bed, 150 to 450 feet thick, of light gray or blue color, but, according to Prof. E. Orton, is not being worked.

The Lower Carboniferous limestone horizon holds a valuable argillaceous deposit, found in a few places in southern Ohio, and in many places in Kentucky a hard flint clay comes into the section. Indeed this clay is one of the two or three strictly first-class clays of the State. It has been worked largely at Sciotoville and Portsmouth, and is hence known as the Sciotoville clay. It also occurs near Logan, Hocking County, and there is called the Logan clay. It has been much used for fire brick.

COAL MEASURES.

These underlie the eastern third of the State, their western border passing through Lawrence, Scioto, Jackson, Vinton, Perry, Licking, Coshocton, Holmes, Wayne, Medina, Summit, Portage, and Trumbull counties.

The lower members are found in the western portion of the area, while the upper members immediately underlie the surface in the middle and eastern parts, toward the Pennsylvania border.

The best clays in the State are found in the Coal Measures, and beds of clay or shale are very numerous throughout the entire series, from the Conglomerate group up to and including the Barren Measures.

CONGLOMERATE GROUP.

The Conglomerate group includes several gray sandstones and conglomerates, 4 or 5 coal seams, 2 thin limestones, 3 or 4 iron-ore seams, and a half dozen clay beds that are known as fire clays and shales. The following is the section:

Section of Conglomerate group of Ohio Carboniferous.

Tionesta sandstone.
Tionesta coal.
Tionesta clay and shale.
Upper Mercer ore.
Upper Mercer limestone.
Upper Mercer coal.
Upper Mercer fire clay.
Lower Mercer iron ore.
Lower Mercer limestone.
Lower Mercer fire clay.
Massillon sandstone (lower).
Sharon shales.
Sharon coal.
Sharon clay.
Sharon conglomerate.

The important beds in this section are the Tionesta clay and shale, the Upper Mercer clay, the Lower Mercer clay, the Quakertown clay and shales, and Sharon clay and shales. The lowest coal seam, the Sharon coal, is also known as the Mahoning coal, the Youngstown coal, the Akron coal, the Massillon coal, and the Jackson shaft coal. Under this is a thin deposit with a small amount of clay, which in turn is underlain by the Sharon conglomerate. It is not used.

SHARON SHALES.

The Sharon shales overlie directly the Sharon coal and vary in thickness from 1 to 50 feet. They are usually dark blue, sometimes almost black, with heavy iron-ore nodules at certain levels. The shales proper have lately become the basis of one of the largest sewer-pipe industries in the United States, at Akron and in its immediate neighborhood. The same deposit is also worked for roofing tile, but the shale is usually high in iron oxide, the amount of this substance ranging between 10 and 15 per cent.

QUAKERTOWN CLAY AND SHALE.

The Quakertown clay and shale occupy a space of 5 to 30 feet between the two divisions of the Massillon sandstones, when such a division occurs. They over-

lie and underlie the Quakertown coal, although the latter may become extremely thin at times. The argillaceous deposits of this age are worked in Summit, Portage, and Stark counties. The Summit deposits furnish stock for the potteries of Springfield, and the Portage bed supplies the Mogadore potteries. The Massillon Fire Brick Company has developed an important deposit at this horizon. It is a streak of hard fire clay 4 to 5 feet thick, immediately underlying the Carboniferous, and representing the Quakertown coal. The bottom of the fire clay is 30 feet above the Sharon coal. This clay resembles the hard No. 1 fire clay of southern Ohio in general appearance. Overlying the coal streak are 10 feet of shale, used for paving blocks.

LOWER MERCER CLAY AND SHALE.

The best-marked horizon of the entire Conglomerate measures is that of the blue or Lower Mercer limestone. Above it there is often a valuable iron ore, while under it is a coal seam of little value. Below the coal the argillaceous deposit is sometimes shale, but generally clay, which is worked to a great extent. This forms the basis of important manufactures in Stark, Tuscarawas, Muskingum, and Hocking counties, especially in the latter. The Columbus Brick and Terra-Cotta Works, at Union Furnace, use it, and it is also worked at Millersburg, Holmes County. There is considerable range in the quality of this clay throughout the State, and it is nowhere of specially high character. The shale or clay immediately overlying the Lower Mercer limestone is promising.

The following two analyses indicate the composition of this clay as mined at Haydenville:

Analyses of Lower Mercer, or Mingo, fire clay.

[E. M. Reed, analyst.]

	1.	2.
Silica	69.92	76.24
Alumina	23.46	16.87
Ferric oxide	.20	.16
Lime	.48	.50
Magnesia	.41	Trace.
Alkalies	1.43	1.09
Water	3.84	5.14
Total	99.74	100

1. Outcropping of vein.
2. Hard clay from mine.

UPPER MERCER CLAY AND SHALE.

The Upper Mercer coal is not of economic importance, but the clay is more persistent than the coal seam. It is a light-colored plastic clay, of widespread occurrence in the State. At Haydenville, Hocking County, it is extensively worked under the name of the Mingo clay, being one of the most valuable clay deposits of the entire series that is included within the Haydenville coal field, the series ranging from the Mercer to the Freeport horizon. The deposit here is 8 to 10 feet thick.

TIONESTA CLAY.

This ranges from a few feet to 20 feet above the last-named deposits, and there is found at times another valuable clay bed. It is used and highly valued in the Union Furnace Works mentioned above. Above this come the Lower Coal Measures.

LOWER COAL MEASURES.

The principal clay deposits of the Lower Coal Measures are as follows:

Clay deposits of Lower Coal Measures of Ohio.

Upper Freeport clay and shales.
Lower Freeport clay and shales.
Middle Kittanning clay and shales.
Kittanning clay.
Ferriferous limestone clay.
Putnam Hill limestone clay and shales.
Putnam Hill limestone horizon.

PUTNAM HILL OR BROOKVILLE CLAY.

The Putnam Hill horizon covers a coal seam called the Brookville coal, and a valuable clay deposit is found in the central Coal Measure counties at this level. It is specially well developed in Muskingum County, and is there largely worked. It continues in good volume and of good character also through Coshocton, Tuscarawas, and Stark counties, where it is largely worked, and it appears promising in Perry, Hocking, and Vinton counties to the south. Like the Lower Mercer clay of the Union Furnace section, it yields on calcination, at least as it is found in the vicinity of Zanesville, a buff or cream-colored brick. This clay is the main basis of the great tile factory at Zanesville. It has also been shipped to North Baltimore, Wood County, for pressed brick. The clay under the Brookville coal is also worked at Greenford, Mahoning County, and New Lexington, Perry County. A red shale, presumably of this age, is also worked here.

In the Zanesville area the clay ranges from 3 to 10 feet thick, with an average thickness of 6 feet. It is usually divisible into an upper or plastic portion and a

lower or more siliceous division. It is largely worked at Canton for the manufacture of paving brick. The following analysis of this shale at North Industry, near Canton, shows its character:

Analysis of shale at North Industry, Ohio.

	Per cent.
Moisture	6.45
Combined water	5.41
Silica	63.09
Alumina	20.17
Oxide of iron	2.12
Alkalies	2.76
Total	100.00

The lower portion of the seam at the same point was analyzed by itself with the following result:

Analysis of lower bed of clay at North Industry, Ohio.

	Per cent.
Moisture	10.42
Combined water	12.72
Silica	41.15
Alumina	28.78
Oxide of iron	3.38
Alkalies	3.55
Total	100.00

This horizon is looked upon as one of the most valuable in the State. The limestone furnishes a good roof for underground workings. Parts of it are good for fire brick. The Harris fire-brick works, 6 miles above Zanesville, on the west side of the river, uses the lower part of the formation. The section here beginning at the top is as follows:

Section near Zanesville, Ohio.

	Feet.
Putnam Hill limestone	...
Putnam Hill limestone shale	11
White clay	4–5
Dark clay	2
Fire clay	2
Sandstone and sandy shale	5
Brown clay	14

The beds known as fire clay and sandstone and sandy shale in this section are used for brick making.

FERRIFEROUS LIMESTONE AND CLAYS.

The Ferriferous limestone and clays underlie the limestone coal with a thickness of 2 to 6 feet. It is light-colored, plastic, of fair quality. Prof. E. Orton, jr., states that this forms a very valuable stoneware clay in the district running from Zanesville down to New Lexington on the Cincinnati and Muskingum Valley Railroad. It is also used in southern Ohio, around Scranton, either as a potter's clay or for shipment as a second-grade fire clay. It is not very high grade at this point.

LOWER KITTANNING CLAY AND SHALES.

The Lower Kittanning clay and shales constitute the great clay horizon of the State, being much more important than any other in Ohio; indeed, Professor Orton considered it equal in value to all other clay sources of the Coal Measures combined. It belongs between the Ferriferous limestone and Lower Kittanning coal, and often fills in the interval between them. In the more important occurrences its thickness ranges between 8 and 30 feet, and sometimes it is even continuous with the clays above the Lower Kittanning, only the coal seam being between, in which case the combined section is not less than 50 feet. The Kittanning clay horizon proper is best seen where it enters the State from Pennsylvania, and again where it leaves the State in its extension into Kentucky. At both of these localities in the Ohio Valley, namely, in Columbiana and Jefferson counties on the one side and in Lawrence County on the other, it shows great quantities of clay of good quality. In Tuscarawas, Stark, and Muskingum counties also it is scarcely less developed. It is extensively mined at Haydenville, Hocking County, and also at Canton, Stark County. The horizon usually yields a white plastic clay of good quality, and this is the foundation of the great eastern Ohio pottery industries. A second and more valuable bed of the clay is found at a few points in Stark, Tuscarawas, and Carroll counties, where it yields a flint clay which is known as the Mineral Point clay, being largely worked at the village of this name and at Canal Dover. Many analyses are given of the white plastic variety, but it is hard to pick out one which can be called thoroughly representative. The products of this horizon are used in the manufacture of saggers, Rockingham, and yellow ware, as well as stoneware. It is also the main dependence of sewer-pipe factories and is even sometimes employed for ordinary fire brick. It is likewise used in large quantities for paving brick. The following analyses are from different points:

Analyses of Lower Kittanning clays, from Ohio.

	1.	2.	3.	4.	5.	6.
SiO_2 (comb)	35.39	35.72	61.86	57.45	55.60	61.86
SiO_2 (free)	17.13	20.65				
Al_2O_3	31.84	29.62	26.02	21.06	24.34	26.02
H_2O	11.68	8.71	9.98	5.90	6.75	9.73
TiO_2	1.68	.....	.....	.....	.....	.....
Fe_2O_3	.67	1.14	.63	7.54	6.11	.63
CaO	.50	.45	.19	.29	.43	1.26
MgO	.19	.14	1.26	1.22	.77	.19
K_2O	.59	.79	.31	3.27	3.00	.31
M_2O	.....	.29	.....	.39	.09	
Fluxes	1.95	2.81	.....	12.71	10.40	1.76
Moisture	.69	1.92	.....	1.90	2.65	.....
Total	100.36	99.43	100.25	99.02	99.74	.....

1. Flint clay, C. E. Holden, Mineral Point. For refractory wares. Ohio Geol. Survey, Vol. VII, Pt. I, p. 221.
2. Flint clay. Sampled in 1892. Ibid.
3. Flint clay. Sampled in 1892. Ibid., p. 139.
4. Ohio Paving Brick Company, Darlington, p. 133.
5. Shale and fire-clay mixture. A. O. Jones Co., Zanesville. Ibid.
6. Haydenville.

MIDDLE KITTANNING CLAY.

At one locality, namely, Oak Hill, Jackson County, the Middle Kittanning clay yields a No. 1 or hard fire clay, and there is the basis of fire-brick manufacture. Nodules of iron ore are seen in many of its outcrops, and these interfere with its use. It has no special peculiarities, but it forms a good adjunct to the Lower Kittanning.

LOWER FREEPORT CLAY.

The Lower Freeport clay shows no great development. At one locality, namely, in the vicinity of Moxahala, Perry County, the seam is found in the condition of hard or flint clay, but of only moderate quality. It contains enough iron to shut it out for use in the highest grades of ware. Usually the clay is of the ordinary type of plastic under clays found in the Coal Measures.

UPPER FREEPORT CLAY AND SHALE.

The Upper Freeport clay and shale is much more important than either of the preceding, for it occurs in great quantity and is more widely distributed than the coal seam from which it gets its name. It assumes a flinty phase at several points. In western Pennsylvania this is known as the Bolivar clay, but in the Muskingum Valley, below Zanesville, it has been worked to a small extent under the name of the Ballou clay. It is not worked at present, except perhaps at Salineville.

LOWER BARREN MEASURES.

The Lower Barren Measures overlie the Lower Coal Measures in order and contain vast deposits of shale, which were just beginning to be used at the time the

Ohio report[a] was written. They serve as the basis of paving-brick industry. These shales are distributed through the entire series, but about the middle portion of this division some deposits of peculiar excellence have been developed, particularly in the Sunday Creek Valley, and that part of the series which is bounded by the Cambridge limestone below and the Crinoidal limestone above seems especially well adapted to paving-block manufacture. No true fire clays are known below the summit of the Pittsburg coal. A good fire clay has been noted under this coal at a few points in Athens County, and at one point in eastern Ohio, namely, at Bellaire, a bed of shale 20 feet or more in thickness directly underlies the Pittsburg coal. This deposit gave good results for paving brick and sewer pipe. Professor Orton is of opinion that

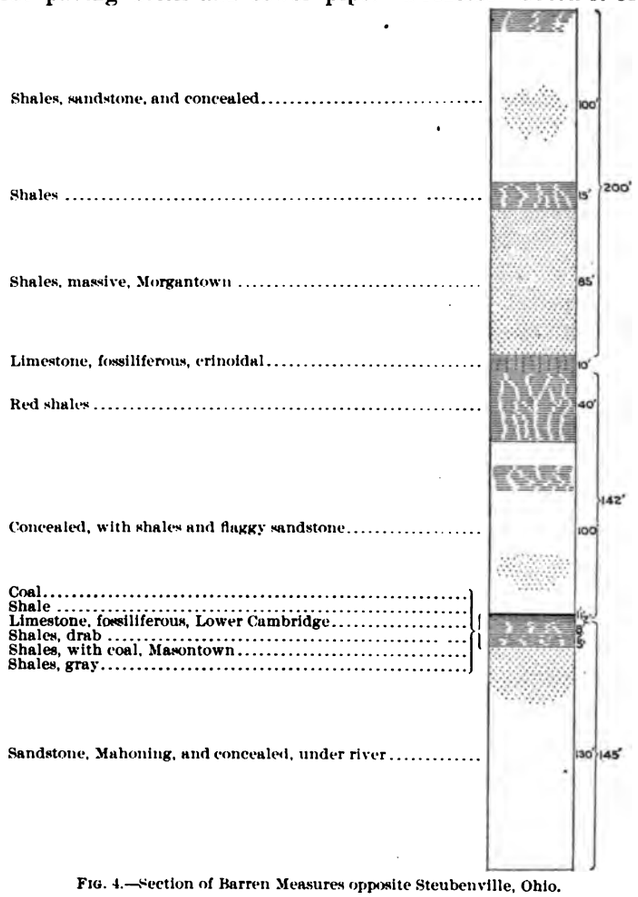


FIG. 4.—Section of Barren Measures opposite Steubenville, Ohio.

certain deposits of red clay and shale in the Barren Measures will also prove suitable for clay products.

In fig. 4 is given a section[b] which illustrates the position of these red shales.

[a] Clays of Ohio: Geol. Ohio, Vol. VII, Pt. I, p. 68.

[b] White, I. C., Bull., U. S. Geol. Survey No. 65, p. 77, fig. 39.

UPPER PRODUCTIVE MEASURES.

This series of beds extends from the base of the Pittsburg coal up to the Cassville shale. Its thickness in Ohio is about 200 feet.

The following section, given by I. C. White, from Bellaire, Belmont County, shows the character of the series:

Section near Bellaire, Belmont County, Ohio.

	Ft.	In.
Waynesburg coal	2	0
Shale, sandy	6	0
Shale	12	0
Limestone	3	0
Concealed	5	0
Coal, blossom, Little Waynesburg		
Concealed	14	0
Coal, blossom, Uniontown	1	0
Shale	4	0
Sandstone	6	0
Shale, argillaceous	20	0
Concealed	32	0
Shale	2	0
Sandstone	3	0
Shale	3	0
Concealed	33	0
Calcareous, with thin limestones	24	6
Coal, Sewickley	27	0
Shales, argillaceous	2	0
Limestone, thin clay in center	8	0
Limestone, magnesian, cement rock	5	0
Clay	1	0
Limestone	11	0
Concealed	11	0
Coal, Redstone, blossom	2	0
Concealed	17	0
Shale	1	0
Coal, Pittsburg	7	0

The area of outcrop forms a narrow, sinuous band, extending in a northeasterly direction from Gallipolis to Steubenville, and southward from there to and beyond Bellaire.[a]

UPPER BARREN MEASURES.

In Ohio these form an area extending through the counties of Belmont, Monroe, Washington, Athens, Meigs, and Gallia.

[a] See map, Pl. I, Bull. U. S. Geol. Survey No. 65.

The following section from Baresville (Hannibal post-office), Monroe County, illustrates well the many shale beds present:[b]

Section at Baresville, Monroe County, Ohio.

	Feet.	Inch.
Coal blossom		
Concealed	145	0
Limestone, Nineveh	6	0
Shale	18	0
Limestone, sandy	2	0
Red shale	14	0
Shale, mostly	21	0
Shale	20	0
Sandstone, laminated	36	0
Red shale	18	0
Sandstone	2	0
Red shale	20	0
Sandstone	3	0
Shale	4	0
Sandstone	3	0
Red shale	13	0
Sandstone	11	0
Shale	4	0
Sandstone	3	0
Shale	3	0
Coal blossom, Jollytown		
Shale	3	0
Sandstone	4	0
Sandy shale	13	0
Sandstone	1	0
Shale	12	0
Sandstone	6	0
Shale	4	0
Sandstone	5	0
Shale	5	0
Sandstone	4	0
Shale	23	0
Sandstone	12	0
Shale	3	0
Sandstone	2	0
Shale	28	0
Sandstone	4	0
Shale	20	0
Coal, Washington	3	1

[b] Quoted by I. C. White, Bull. U. S. Geol. Survey No. 65, p. 28, fig. 7, from Ohio Geol. Survey, Vol. II, p. 587, map xiii, sec. No. 11.

Section at Baresville, Monroe County, Ohio—Continued.

	Feet.	Inch.
Clay	2	0
Shale	7	0
Sandstone	2	0
Shale	5	0
Sandstone	1	0
Shale	3	0
Concealed	156	0
Sandstone, Waynesburg	15	0
Shale	3	0
Coal, Waynesburg		

The following analyses give the composition of many of the several important grades of clay worked in Ohio:[a]

Analyses of Ohio stoneware clays.

Constituent.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Silica (combined)	25.60	28.61	23.88	27.68	27.74	25.40	29.35	25.48	30.36	32.33
Alumina	19.08	23.01	19.31	22.95	23.08	21.13	23.05	20.80	24.88	26.60
Water (combined)	5.57	8.03	5.08	6.74	6.88	6.29	7.39	5.72	6.96	7.57
Clay base	50.25	59.65	48.27	57.37	57.70	52.82	59.79	52.00	62.20	66.50
Silica (free)	43.73	34.79	45.91	36.58	35.73	40.81	35.85	42.65	33.19	24.11
Titanic acid	.29	.35	.....	.....	.....	.....	.55	.....	.....	.....
Sandy impurities	44.02	35.14	45.91	36.58	35.73	40.81	36.40	42.65	33.19	24.11
Oxide of iron	1.26	1.50	.....	1.28	1.31	1.28	.99	1.20	1.17	2.00
Lime	.60	.41	.....	.45	.51	.51	.58	.42	.56	.47
Magnesia	.63	.62	.....	.37	.46	.18	.58	.37	.47	.63
Potash	2.14	1.26	.....	1.81	1.71	1.42	1.45	2.28	2.27	3.20
Soda	.02	.....	.....	.15	.22	.38	.....	.27	.....	.26
Fluxing impurities	4.65	3.81	4.80	4.06	4.21	3.77	3.60	4.54	4.47	6.56
Moisture	.94	1.97	1.02	2.05	2.18	1.65	1.11	1.00	1.38	2.48

1. Brumage's stoneware clay, Roseville.
2. Allen's stoneware clay, Roseville.
3. Walker's clay used for cooking wares, Roseville.
4. Zanesville Stoneware Company, clay ground in tracing mill for hand turning.
5. Zanesville Stoneware Company, same clay washed and pressed for use in jollies.
6. Bagley & Roberts, Zanesville. Clay for cooking ware.
7. Uniontown stoneware clay.
8. Akron stoneware clay. Average of several samples selected in different plants.
9. New Brighton, Pa. Sample from factory there for comparison.
10. Steubenville. Stoneware clay deficient in fire qualities.

[a] Ohio Geol. Survey, Vol. VII, Pt. I, p. 94.

Analyses of Ohio shale clays used in the manufacture of paving brick and sewer pipe.

Constituent.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Silica (total)	57.15	58.30	57.10	49.30	57.45	55.60	58.20	58.38	57.28	57.40	53.38	56.18	52.19	56.61
Alumina	20.26	19.67	21.29	24.00	21.06	24.34	22.47	20.89	21.13	21.20	19.36	26.70	14.61	21.63
Water (combined)	5.50	5.15	6.00	9.40	5.90	6.75	6.15	7.53	5.22	7.75	.....	.....	5.62	.....
Clay and sandy impurities	82.91	83.12	84.39	82.70	84.41	86.69	86.82	86.80	83.63	86.35	.....	.....	72.42	.....
Oxide of iron	7.54	7.43	7.31	8.40	7.54	6.11	5.63	5.78	8.52	6.57	14.86	7.43	10.00	7.08
Lime	.90	.84	.29	.56	.29	.43	.62	.44	5.79	1.00	1.48	.52	.....	1.11
Magnesia	1.62	1.35	1.53	1.60	1.22	.77	.98	1.57	2.13	1.40	1.06	1.12	.....	1.41
Potash	3.05	3.04	3.44	3.91	3.27	3.00	3.08	4.68	.....	4.10	.....	.....	.....	3.51
Soda	.58	.73	.61	.19	.39	.09	.42	.34	.....	1.00	.....	.....	.....	.48
Fluxing impurities	13.69	13.39	13.18	14.63	12.71	10.40	10.73	12.81	16.44	14.07	.....	.....	4.96	.....
Moisture	2.70	2.65	1.30	1.20	1.90	2.65	1.65	.....	.....	.....	.....	.....	12.62	.....

1. Shale used by Bucyrus Brick and Terra Cotta Company; mined at Glouster, on horizon of Cambridge limestone.

2. Same shale, with addition of one-fourth leached drift clay, added to increase plasticity; same place.

3. Shale from Royal Brick Company, Canton; from the horizon of Putnam Hill limestone.

4. Shale from Waynesburgh Brick and Clay Manufacturing Company; from the Middle Kittanning horizon.

5. Shale from the Ohio Paving Company, Columbus; mined at Darlington, from the Lower Kittanning horizon.

6. Shale and fire clay mixture, from the A. O. Jones Company, Zanesville; Kittanning horizon.

7. Shales and fire clays, mixed, from the T. B. Townsend Brick Company, Zanesville; Freeport shales and Kittanning fire clays.

8. Shales from Columbus Sewerpipe Company; Huron shale horizon.

9. Bedford shale; from northern Ohio.

10. Same shale, different sample and another chemist.

11. Shales from Royal Brick Works, Canton; Putnam Hill horizon.

12. Same shales from another opening.

13. Shales from Holloway Paving Brick Company, North Industry; Lower Mercer.

14. Average of first ten analyses.

Analyses of Ohio fire clays used in paving brick and sewer pipe.

Elements.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Silica (total)	54.53	51.72	51.82	62.81	57.80	64.10	70.00	57.75	59.75	65.90	77.65	59.20	58.10	56.71
Alumina	27.88	30.10	28.69	21.41	25.54	21.79	19.35	28.66	27.45	24.20	12.78	26.10	29.60	33.72
Water	8.87	9.95	9.67	6.52	8.35	6.05	5.39	8.35	5.45	4.80	4.10	8.55	8.70	6.89
Clay and sand impurities	91.78	91.77	90.18	90.74	91.69	91.94	94.65	95.76	92.65	94.90	94.53	93.85	96.40	97.32
Titanic acid	1.26	1.35	.72	1.26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ferric oxid	2.41	1.94	2.77	2.63	2.51	2.51	2.22	1.94	.....	2.00	3.32	2.70	1.20	.....
Lime	.42	.62	.77	.58	.25	.10	.15	.15	.75	.80	.55	1.06	.40	.29
Magnesia	.68	.53	1.41	.85	.61	.58	.34	.24	.65	.54	.45	.75	.54	1.58
Potash	3.31	2.74	2.57	2.89	2.51	2.62	2.90	2.55	3.58	2.30	1.30	1.53	1.75	1.01
Soda	.12	.....	.25	.21	.18	.03	.....	.....	.....	.....	.....	.....	.....	.....
Fluxes	6.94	5.83	7.77	7.18	6.06	5.84	5.61	4.88	4.98	5.64	5.62	6.03	3.89	2.88
Moisture	.76	1.05	1.72	1.47	2.25	1.10	.....	.....	.....	.....	.....	.....	.....	.....

1. N. U. Walkers, sewer-pipe clay, Columbiana County.
2. Freeman's sewer-pipe clay, Jefferson County.
3. Island Siding clay, Jefferson County; fit for sewer pipe.
4. Same clay, another sample.
5. E. Palestine, paving-brick clay, Upper Freeport horizon.
6. Massillon Fire Brick and Stone Company, mixture of fire clay with shale and surface clays used for paving blocks.
7. Toronto sewer-pipe clay, top.
8. Toronto sewer-pipe clay, bottom.
9. Average, top and bottom, Toronto.
10. Empire sewer-pipe clay.
11. Elliottsville sewer-pipe clay.
12. Elliottsville sewer-pipe clay.
13. Croxton Run sewer-pipe clay.
14. N. U. Walker's sewer-pipe clay.

Analyses of flint clays from Ohio.

	1.	2.	3.	4.
SiO_2 (combined)	35.39	35.72	44.34	59.92
Al_2O_3	31.84	29.62	40.05	27.56
H_2O	11.68	8.71	14.23	9.70
SiO_2 (free)	17.13	20.65	.26	.....
TiO_2	1.68	.....	.....	.....
Fe_2O_3	.67	1.14	.80	1.03
CaO	.50	.45	.27	Trace.
MgO	.19	.14	Trace.	Trace.
K_2O	.59	.79	Trace.	.67
Na_2O	.....	.29	Trace.	.....
Moist	.69	1.92	.....	1.12
Total	100.06	99.43	99.95	100
Fluxes	1.95	2.81	1.07	1.70

1. Flint clay from C. E. Holden, Mineral Point, Lower Kittanning, 1883.
2. Same, finely ground and averaged, 1892.
3. Gaylord clay, Scioto County, Ohio, Portsmouth Fire Brick Company.
4. Salineville flint clay; Furnace Fire Brick Company, Salineville, Ohio.

PLEISTOCENE.

Pleistocene clays are found in all parts of the State, but they are used chiefly for common brick and drain tile. The alluvial clays along some of the rivers have been utilized for paving brick.

CLAY-WORKING INDUSTRY.

Ohio is the leading producer of clay products in the United States, producing the largest quantity of paving brick, fancy brick, sewer pipe, tile (other than drain), and all grades of pottery except chinaware, sanitary ware, and electrical supplies. The common brick industry is well developed at many localities, being based specially on the surface or drift clays, which are common in nearly all parts of the State. Yards are located chiefly around the cities of Cleveland and Columbus.

The great abundance of fire clays and red-burning shales form the basis of a flourishing pressed-brick industry, and many are made both by the stiff mud and dry press process. Among the localities at which this class of products is made may be mentioned Columbus, Shawnee, Portsmouth, and Cleveland.

Paving bricks are made in enormous quantities from the Carboniferous shales and fire clays of low grade found in the Coal Measures of the eastern half of the State. In a few cases the surface clays are drawn upon, as in the Ohio Valley,

where the alluvial river clays are employed. The distribution of the paving-brick plants in this State can be seen from the map, Pl. VIII. The Ohio paving bricks, especially those made at Canton and other localities, bear a high reputation.

Terra cotta is manufactured in very small quantities in Ohio notwithstanding the leading position which she occupies in the line of clay-working States.

Floor tile of plain colors and the encaustic variety form an important item of production, being partly from native shales and fire clays at Zanesville and Hamilton. Roofing tile of the Roman type are produced at Akron, and glazed tile at Hamilton.

In the production of fire brick Ohio stands second to Pennsylvania, but those made from the well-known fire clays occurring at Mineral Point, Portsmouth, Sciotoville, Haydenville, etc., bear a high reputation.

It is in the pottery industry that Ohio becomes especially prominent. Stoneware is made in vast quantities from the shales and impure fire clays of the Coal Measures, factories being located at Steubenville, East Liverpool, Palestine, Zanesville, Mogadore, Massillon, Roseville, and other towns. Rockingham and yellow ware are also produced, though the value is not more than one-quarter that of the stoneware. Yellow and Rockingham are important products, but are not manufactured to the same extent as stoneware, although they are among the earlier forms of ware made in the State. Red earthenware is a product of equal importance. White ware, chiefly of the C. C. and white granite variety, is actively produced at East Liverpool, which is one of the two great potting centers of the United States, the ware made here supplying the western more than the eastern markets. Other whiteware factories are in operation at Tiffin, East Palestine, Akron, Steubenville, Wellsville, Toronto, etc. The Rookwood pottery, made at Cincinnati, and the Weller pottery, manufactured at Zanesville, form a grade of art pottery which is unlike any produced elsewhere.

Some china is produced at East Liverpool, and electrical supplies are manufactured at the same city, but the quantity manufactured is not so large as that molded in New Jersey or New York.

Sewer pipe is turned out in great quantities at Akron, the production being controlled by a few large corporations; in fact, Ohio at the present time represents the center of the sewer-pipe industry.

The total value of clay products for the last seven years is given below, together with the itemized production for 1900.

Value of clay products of Ohio from 1894 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1894	$10,668,498	1	16.52
1895	10,649,382	1	16.30
1896	10,609,571	1	15.96
1897	11,067,684	1	17.75
1898	12,667,627	1	17.34
1899	16,500,625	1	17.22
1900	18,304,628	1	19.03
1901	21,574,985	1	19.58

Value of clay products of Ohio in 1900 and 1901.

	1900.	1901.
Common brick	$2,232,090	$2,725,912
Front brick	433,086	612,718
Vitrified brick	1,118,106	1,443,537
Fancy brick	47,155	60,908
Fire brick	1,340,775	1,287,059
Stove linings	(a)	(a)
Drain tile	715,874	707,409
Sewer pipe	2,243,386	2,735,703
Terra cotta	2,857	(a)
Fireproofing	351,884	357,284
Tile (not drain)	690,257	996,005
Miscellaneous	491,735	599,682
Earthenware and stoneware	949,451	952,329
Yellow and Rockingham ware	175,176	206,843
C. C. ware	1,056,226	726,321
White graniteware	2,767,837	2,710,726
Semivitreous porcelain ware	2,251,213	3,520,008
Electrical supplies	247,135	325,664
Miscellaneous pottery	549,994	400,957
Clay, mined	143,547	152,785

a Included in miscellaneous.

PENNSYLVANIA.

The geologic formations of Pennsylvania range from the early pre-Cambrian crystalline rocks to the youngest formations of the Pleistocene.

In the western portion of the State, except the northwestern counties, the rocks are almost all of Carboniferous age. The beds are bent into a series of gentle folds, but often the exposure of the lower or older beds is due partly to the overlying beds having been worn away.

To the east the rocks become highly folded in the central counties of the State, so that the strata often have a very steep dip, and not only the Carboniferous but also the lower-lying Devonian and Silurian formations are exposed, giving rise to bands which extend in a general northeast-southwest direction.

The eastern portion of the State is underlain largely by crystalline rocks and more or less altered Cambrian and Ordovician sediments, which in many cases yield a mantle of residual clay that may be of considerable economic value.

In the extreme eastern portion of the State there is a narrow strip of Coastal Plain formations, but with the exception of the Columbia loams they have little value in Pennsylvania. North of the line of the terminal moraine the drift clays are not uncommon and are found in many of the river valleys.

RESIDUAL CLAYS.

These may occur at almost any locality in the area lying south of the region covered by the glacial drift. The causes governing their formation and distribution have been explained on a previous page. The most important belt of these deposits is probably that found in the Great Valley, all along the line of which, as well as in the South Mountain region, there are great quantities of white and variegated clays. These clays have been derived from the decomposition of hydromica slates, which are interstratified with Ordovician limestones and quartzites, talcose slates, and limestones of Cambrian age. In places the deposits contain iron ores, which have been worked, but the widespread utilization of the clays for the manufacture of clay products is comparatively recent, although mention is made of their former use for making bricks[a] and in paper manufacture.[b]

[a] Second Pennsylvania Geol. Survey, Rept. D 3, Vol. II, p. 364.
[b] Ibid, p. 366.

The composition of such a clay from the Hunter mine, on the Kemp farm, is as follows:

Analysis of clays from Hunter mine, on Kemp farm.

Silica	66.17
Alumina	19.89
Lime	.26
Magnesia	1.902
Iron protoxid	.783
Alkalis and undetermined	6.211
Water	4.784
Total	100.000

The clays are referred to in the Pennsylvania reports,[a] but from the standpoint of the clay worker the most recent important paper is one by T. C. Hopkins,[b] according to which a kaolin deposit lies 1½ miles north of Glen Loch station, on the north side of Little Chester Valley. This kaolin is near the contact of the Chester Valley (Ordovician) limestone and the North Valley Hill (probably Cambrian) sandstone. It is said to show great similarity to the South Mountain kaolins of Cumberland, Franklin, Adams, and York counties.

"The most extensive developments have been on the Gettysburg Railway, south of Mount Holly, and on the Hunters Run and State Belt Branch Railway. Although known for a long time, the commercial introduction of these clays is of recent date. The white clay is found in many of the ore mines which were worked in former years, and may either underlie or overlie the ore.

"Another clay-washing plant is working a deposit of clay a mile east of Henry Clay station, the pits being sunk on the mountain side and having a depth of 90 to 100 feet. At Cranes siding, 1 mile above the Hunter Run station, is a deposit of clay which is worked to supply a clay-washing plant also located here. The kaolin comes from the old Crane iron ore mine, where it underlies the ore on the south slope of South Mountain. The mining is done by tunneling, and the clay run out on tram cars. It is used for paper filler and pottery."

Though these clays occur over a large portion of southeastern and central Pennsylvania, the most productive localities are South Mountain, Cumberland County; Mertztown, Berks County; and Ore Hill, near Roaring Springs, in Blair County. Pits have also been opened at the Upper Mill station on the Hanover and Gettysburg Railroad, at Cranes Siding, Henry Clay, and Lowell station on the Hunters Run and State Belt Railroad, at Montello, near Reading (worked for fire brick), north of Glen Loch station, in Little Chester Valley, and north of Conshohocken.

[a] Notably D 3.

[b] The white clays of southeastern Pennsylvania: Eng. Min. Jour. Vol. LXX, p. 131; and article on Kaolin: Min. Indus., Vol. VII, p. 156. Most of the information under this heading, where not credited to the Pennsylvania geological survey, has been obtained from these two papers.

Paper clay is obtained from a point one-half mile south of Mertztown, Berks County, and kalsomine clay at Maple Grove, southeast of Mertztown. Other deposits of white clay are seen in many of the old ore pits in Berks and Lehigh counties, notably Ironton, Klines Corners, Friedensville, west of Kutztown, on Neversink Mountain, at Reading. Residual clays are also found in Caln Township, Chester County, having been derived from hydromica schist, which is interbedded with limestone.[a] In east Caln Township, near Baldwins station, variegated clays occur.[b] Other localities are in west Whiteland Township, the type of variegated clay being one commonly found in York and Lancaster counties.[c] Still other deposits occur northwest of Whitehorse, in east Whiteland township,[d] near Warren Tavern post-office,[e] and New Garden township.[f] Red residuals are known in Penn Township, Chester County.[g] Small deposits of white residual clay have been mentioned as occurring 1 mile from Truemans Mill.[h] The residual clays found near Hanover have been used for making bricks.[i]

The white clays have been used to some extent for chinaware, but their chief application is in paper manufacture and for kalsomining. They have also been employed in the manufacture of white brick encaustic tiles, stove linings, and fire brick.

"The first use made of the clay was in 1893, when the Penn Tile Works were established at Asper, about the same time that the brick works at Pine Grove began operations. About three years later two clay-washing plants were established on Mountain Creek, between Pine Grove and Mount Holly Springs.

"The works at Pine Grove manufacture ornamental bricks of different kinds. The white clay, together with some colored clay, is used simply as a bond, the body of the material being a slate for reddish colored brick, and a greenish talcose slate for light colored ones. The slate is brought to the works by railway from the slate quarry, 3 miles to the southwest, the talcose rock is hauled from a quarry three-quarters of a mile distant, and the clay is brought by rail from Laurel station, also 3 miles distant."

A second type of white residual clays or kaolin are those of Delaware and Chester counties which have been formed by the weathering of pegmatite veins. These deposits have been worked for a number of years, especially those near Kaolin post-office, in Chester County, where kaolin has been dug since 1839. The vein here occurs in mica-schists and strikes northeast-southwest, having a width of 120 to 150 feet, with at least one parallel vein. Near the surface the color of the kaolin is buff or yellow, due to the intermixture of soil from neighboring rocks. The clay is mined by means of circular shafts with temporary crib-work linings. These have a depth usually of 80 to 100 feet, but one reached 130 feet. The kaolin is washed and the separated sand is used in part for silica brick and in part is ground and sold to the

[a] Second Pennsylvania Geol. Survey, Rept. C 4, p. 272.
[b] Ibid., p. 274.
[c] Ibid., p. 275.
[d] Ibid., p. 277.
[e] Ibid., p. 279.
[f] Ibid., p. 325.
[g] Ibid., p. 340.
[h] Ibid., p. 137.
[i] Idem, Rept. CC, p. 208.

potteries as flint. The washed kaolin is shipped to the potteries at East Liverpool, Ohio, and Trenton. N. J.

Other mines occur near Brandywine Summit, in Delaware County, and up to 1895 the kaolin mined at these was washed. Since that time the production of white kaolin has ceased, and one of the two companies located at this locality is engaged in mining feldspar from the pits, while the other is utilizing, for the manufacture of ornamental brick,[a] the poorer kaolin, which had been thrown on the dump in former years.

At Elam post-office, about 3 miles southeast of the Brandywine Summit kaolin mines, is a white clay which Hopkins considers to be the waste from some kaolin vein. It was worked at one time for the manufacture of fire brick.

Analyses of Pennsylvania white residual clays.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Al_2O_3	9.44	17.30	17.43	31.29	26.96	26.12	20.10	31.29	36.25	20.53
SiO_2	84.05	73.80	73.30	51.90	59.83	60.37	67.10	51.90	46.26	67.71
H_2O	2.18	4.69	4.68	8.90	9.56	5.42	5.90	8.90	13.54	3.12
Fe_2O_3	0.28	0.35	0.37	Tr.	1.98	0.69	3.90	.....	1.64	7.78
CaO	0.23	.....	0.02	Tr.	0.11	0.05	0.10	Tr.	0.19	0.39
MgO	1.35	1.18	1.28	1.52	0.50	1.93	0.70	1.52	0.32	0.04
K_2O	2.37	2.49	2.99	4.01	0.94	5.74	2.00	4.01	1.69	.29
Na_2O	0.28	0.20	0.17	2.99	0.24	0.29		2.99	0.85	
Total	100.18	100.01	100.24	100.61	100.12	100.61	99.80	100.61	100.74	99.86

	11.	12.	13.	14.	15.	16.
Sand	37.17	10.96	51.30	45.52	50.16	30.46
Feldspar	0.54	0.19	2.66	1.31	1.19	1.62
Anhydrous clay	56.75	84.47	42.16	49.77	46.35	59.90
Water	5.54	4.38	3.88	3.40	2.30	8.02
Total	100.00	100.00	100.00	100.00	100.00	100.00

1. Crude white clay, Upper Mill.
2. Refined white clay, Upper Mill.
3. Mixed white clay, Mount Holly.
4. White land white clay, Chester County.
5. Conshohocken, parti-colored clay.
6. Barren Hill gray clay.
7. Chestnut Hill.
8. Glen Loch.
9. Brandywine Summit.
10. Brandywine Summit.
11. Jno. Allen's white clay, South Mountain.
12. Philadelphia Clay Company, South Mountain.
13. Mr. Hooper, South Mountain.
14. White clay, Latimore.
15. Damourite slate, Latimore.
16. Conshohocken parti-colored clay.

[a] See Second Pennsylvania Geol. Survey, Report C5 and Ann. Rept. for 1885, p. 571.

SILURIAN AND DEVONIAN.

The formations of these series, which contain vast beds of shale, occupy a large area in the eastern and south-central portion of Pennsylvania and should afford an excellent field of exploitation for the clay worker.

The Devonian is found over large areas in the extreme northwestern corner of the State in Erie County, as well as in Tioga, Bradford, Susquehanna, Wayne, and Pike counties. In the eastern counties the beds are apt to be sandy. To the south and southeast the rocks are much folded, and the Devonian and Silurian formations appear as a series of bands in Lackawanna, Luzerne, Carbon, Cumberland, Snyder, Juniata, Perry, and other counties, and the shale beds found in them are worked at several localities for the manufacture of both building and paving brick. Their general distribution is indicated on the map (Pl. III), but for more detailed information the map issued with the Final Summary Report of the Pennsylvania Geological Survey for 1893 should be consulted. For locating suitable shale beds in these formations it would be necessary to do more or less field work. The Clinton shales have been dug for brickmaking near Laurelton and Hartleton townships of Union County.[a] Mr. A. W. Sheafer, of Pottsville, informs me that the shales are worked at Pine Grove, Williamsport, Sandy Run (Mauch Chunk shale), and Reading (Hudson shale).

CARBONIFEROUS.

The clays and shales derived from the Carboniferous rocks of Pennsylvania are foremost among this type of economic deposits found in the State. They include a wide range of materials, from impure sandy shales, of little value except for the manufacture of common brick, up to the highest grade of refractory clay. It is impossible to enter upon a detailed discussion of these shales in the space which is here available, and unfortunately, but little information regarding them is to be found in the reports of the Pennsylvania Geological Survey, for at the time these were written shales had not come into extensive use for the manufacture of clay products, but the abundance of them is shown by the various published sections given in these reports under the different counties, and also by the sections on page 232. Of more importance, however, are the fire clays, which often occupy well-marked stratigraphic positions, and in some places form persistent and important beds that are traceable over wide areas.

The Carboniferous rocks cover a large portion of the western half of Pennsylvania, as is shown on the accompanying map (Pl. III), and from what follows it will be seen that the refractory beds of aluminous materials have received much attention in the various geologic publications. The occurrences are taken up in regular order, beginning with the oldest.

CONGLOMERATE GROUP.

This member of the Carboniferous is composed chiefly of sandy beds, as sandstone and conglomerates, but there are several beds of shale and coal. The latter are often underlain by shale and in some instances by fire clay.

[a] Second Pennsylvania Geol. Survey, Rept. F3, p. 123.

MERCER OR ALTON FIRE CLAYS.

On the Wilmarth coal tract, southwest of Wilmarth station, Elk County, the Alton upper coal is found to be underlain by a fire clay, ranging from 20 to 61 feet thick, the section as exposed at an air shaft being given below.[a] It is probable that this entire thickness does not represent pure fire clay.

Section southwest of Wilmarth station, Elk County, Pa.

	Feet.
Soil	10
Sandstones	30–40
Coal	1–41
Fire clay	20–61
Alton lower coal	4½–65½

The following analyses, No. 1 by J. M. Stinson and No. 2 by A. S. McCreath, show the composition of this clay:

Analyses of Mercer or Alton fire clay from Pennsylvania.

	1.	2.
Silica	51.72	56.27
Alumina	21.736	23.225
Iron protoxide	7.875	5.4
Titanic acid	.87	1.19
Lime	.06	.01
Magnesia	2.378	2.086
Alkalies	4.581	4.039
Ignition	10.78	7.78
Total	100.00	100.00

At Parker Township, in northern Butler County, between Columbia Hill, in Allegheny Township, and Donnelly station,[b] the following section is shown:

Section in Parker Township, Butler County, Pa.

		Feet.
Homewood sandstone	Massive sandstone	15
	Shales and slates	50
Bituminous shale (Mercer)		3
Sandy fire clay		12
Blue slate		5
Bituminous shale (Mercer)		5
Olive shale and blue slate, nodular ore at top		47
Shaly sandstone		20
Blue and olive shale		43
Sandstones, thinly beddede		20
Total		220

[a] Second Pennsylvania Geol. Survey, Rept. RR, p. 140. [b] Idem, Summary Final Rept., Vol. III, Pt. I, p. 1897.

On Millers Run, in the Broadtop district, the Mercer coal is underlain by 10 to 15 feet of fire clay, while at Robertsdale, Huntington County, it is said to be only 1 to 2 feet thick.

In Beaver, Lawrence, and Mercer counties[a] there seems to be several shale beds, but no fire clays. In the columnar sections given in the atlas of Rept. RR., Second Pennsylvania Geological Survey, fire clays are indicated under the Alton coals of the Pottsville conglomerate at Lafayette, Clermont, and on the Butterfield lands, McKean County; at Johnson Run, Norwich, and Benezette, Elk County; and at Cameron, Cameron County.

THE SHARON OR MARSHBURG UPPER COAL FIRE CLAY.

In Elk County a bed of fire clay is often found associated with the upper Marshburg coal bed between the Olean conglomerate and the Kinzua Creek sandstone. It is frequently of sufficient thickness and of proper quality to be worth mining. This bed has been worked in western Benezette Township, between Benezette and Rock Hill, Elk County, and again 1½ miles southwest of Benezette, where it ranges from 4 to 9 feet in thickness, but may be less.[b] Fig. 5 shows the section at Benezette. At one locality it was 50 feet above the Mauch Chunk red shale. The fire clay also underlies the coal in Spring Creek Township on Laurel Run. The following analyses indicate the composition of this clay:

Analyses of Sharon or Marshburg Upper Coal fire clay.

Elements.	1.	2.	3.
Silica	44.45	44.045	44.960
Alumina	38.945	39.445	38.172
Iron protoxide	2.135	.940	.513
Titanic acid	.....	.....	1.240
Lime	.173	.075	.12
Magnesia	.155	.115	.084
Alkalies	.760	.720	.071
Sulphuric acid	Trace.	Trace.	.....
Water and organic matter	13.287	14.138	14.840
Total	99.905	99.478	100.900

1. Jones mine, hard, compact, conchoidal fracture, and pearl gray.
2. Fletcher mine, similar.
3. Barr and Radcliff mine, hard and brittle.

All three analyzed by A. C. McCreath.

In Mercer County the Sharon coal is underlain by fire clay in places.[c]

[a] H. M. Chance, Second Pennsylvania Geol. Survey, Rept. V, Pt. II, p. 190 et seq.
[b] Idem, Rept. RR, p. 260.
[c] Idem, Rept. Q3, p. 33.

SAVAGE MOUNTAIN FIRE CLAY.[a]

In the report on Bedford and Fulton counties it is stated that no good plastic fire clay was seen in the Broadtop region, and that most of the clays contained considerable iron. The Savage Mountain fire clay reaches the southwest corner of Bedford County in Londonderry Township. No exposures of it are found, but it is mined on the Baltimore and Ohio Railroad in Somerset County, just beyond the line of Bedford County. The deposit in places reaches a thickness of 21 feet. Much of the clay makes only second-grade products, but at least one-half in the present workings makes bricks of first quality. These clays make excellent coke-oven bricks. Analyses of the clays are given below.

Analyses of Savage Mountain fire clay from Somerset County.

	1.	2.
SiO_2	54.65	55.21
Al_2O_3	30.74	31.18
Fe_2O_3	.08	.07
CaO	.19	.18
MgO	.13	.11
Alkalies	.11	.23
Water	14.02	13.02
Organic and loss	.....	.23

LOWER PRODUCTIVE MEASURES.

These contain a number of important fire-clay beds, as may be seen from the following sections:[b]

Section of Lower Productive Measures in vicinity of Bolivar and Lockport, Pa.

	Feet.	Inches.
Upper Freeport coal, bed E	8	0
Clay shales	6	0
Shales with ore masses	3	0
Sandstone and sandy shales	10	0
Fire clay, worked	3	0
Limestone, impure	8	0
Thin-bedded sandstones	7	0
Clays, slates, and shales	15	0
Lower Freeport coal, bed D	2–3	0
Clay, impure	3	0
Limestone	5	0
Clay shales	10	0
Sandstones	7	0
Sandy fire clay	3	0
Slates and shales	20	0

[a] Second Pennsylvania Geol. Survey, Rept. TT, p. 336.
[b] Idem, Rept. H5, p. 88.

Section of Lower Productive Measures in vicinity of Bolivar and Lockport, Pa.—Continued.

	Feet.	Inches.
Sandstones	10	0
Gray slates	6	0
Coal bed D	1	10
Fire clay, impure	6	0
Limestone, Johnstown cement bed	2–4	0
Dark slates and shales	20	0
Sandy shales with ore nodules	20	0
Carbonate iron-ore band	0	6
Black slates	10	0
Coal bed C	1	0
Slates	8	0
Shales	10	0
Black slate and shale	30	0
Coal bed B	5	0
Clay	5	0
Sandstone	10	0
Shales and clayey slates	13	0
Coal	7	0
Sandstone	5	0
Coal bed A	1	0
Fire clay	2	0
Shales	10	0
Sandstones, heavy compact	30	0
Coal bed A	1	8
Fire clay, plastic	4	0
Interval to Piedmont sandstone	15	0
Total	330	6

Section of Lower Coal Measures at Karthaus, Clearfield County, Pa.

[See fig. 6.]

	Feet.	Inches.
Coal, Upper Freeport	6	0
Fire clay	2	6
Sandstone, brown	45	0
Coal	10	0
Fire clay	2	0
Limestone, siliceous	3	6
Shale	1	0
Sandstone, brown	26	0
Coal, Lower Freeport	3	0
Slate	1	6
Sandstone, gray, Freeport	37	0
Coal, Upper Kittanning	3	2
Shale, containing iron ore	11	0
Coal, Middle Kittanning	1	0
Sandstone and slate	21	0

FIG. 5.—Section at Benezette, Elk County, Pa.

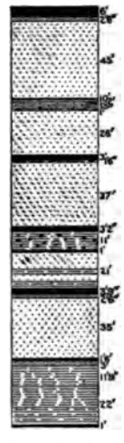


FIG. 6.—Section of Lower Coal Measures at Karthaus, Clearfield County, Pa.

Section of Lower Coal Measures at Karthaus, Clearfield County, Pa.—Continued.

	Feet.	Inches.
Coal, Lower Kittanning: Coal 1 foot; Slate 3 inches; Coal 2 feet 6 inches	3	9
Fire clay	2	6
Sandstone, brown	35	0
Coal, Clarion	1	6
Fire clay, ferruginous	3	0
Shales, containing iron-ore band	11	9
Shales and slate	22	0
Coal, Brookville	1	0
No. XII conglomerate	--	--
Total	245	0

The above sections show an abundance of coal beds, and accompanying them a good development of fire clays; in fact it is the most important source of the Pennsylvania fire clays. The clays are found in greater or less quantity underlying the Brookville and Clarion coal, the Ferriferous limestone, and the Kittanning and Freeport coals.

BROOKVILLE COAL UNDER CLAY.

The Brookville coal bed is underlain by a persistent and widely distributed clay. It is used for making fire brick at Sandy Ridge, Blueball, Woodland, and Hope Station, Clearfield County; Benezette, Elk County; Parkville, Jefferson County; and Queens Run and Farrandsville, Clinton County. It has also been extensively worked at Johnstown, Cambria County, where it is over 4 feet thick, but shows two kinds of clay.[a] It is often too impure for the manufacture of fire brick.

An analysis of this clay is given in the table below. The same bed is worked by the Burl Firebrick Company at Blacklick, Indiana County, the mine being located on the west slope of Chestnut Ridge, about 1½ miles east of the village of Blacklick. The clay overlies the Pottsville conglomerate at the base of the Lower Productive Measures, and varies in thickness from 3 to 11 feet, but averages from 7 to 8 feet. It contains many ore balls, and has to be hand picked, but can be mined by open pits.[b] These mines have been in operation for about thirty-five years.

The Brookville clay as found at Bolivar is plastic, and the same stratum also appears on Blacklick Creek, but there it is somewhat impure. This should not be confounded with the hard fire clay used at the Bells Mills, on Blacklick Creek, the latter being 20 feet lower stratigraphically and not recognizable at Bolivar.

A section from the Upper Freeport down to the Lower Freeport is given on page 65, Rept. H4, Second Pennsylvania Geological Survey.

At a point 2½ to 3 miles west of Blueball station, on the Tyrone and Clearfield

[a] Second Pennsylvania Geol. Survey, Rept. HH, p. 146. [b] See analyses 18 and 19 in table on p. 220.

branch of the Pennsylvania Railroad, are the following sections, the second being in a shaft.[a] The mines are near the top of an anticlinal axis, similar to that at Sandy Ridge.

Section near Blueball station, Clearfield County, Pa.

	Ft.	In.
Surface clay	2	0
Impure fire clay	7	0
Hard impure fire clay	4	10
Soft impure fire clay.		

Section in shaft near Blueball station, Clearfield County, Pa.

	Ft.	In.
Surface and loose stuff	6	0
Coal smut	0	2
Fire clay	6	0
Dark fire clay	1	6
Soft fire clay	0	4
Hard fire clay	3	0
Brown sandstone	0	2
Massive sandstone.		

Fire clay also occurs three-fourths of a mile northwest of Woodland station and one-half mile southeast of the Hope mine. At Barrett's station, on the Tyrone and Clearfield branch of the Pennsylvania Railroad, fire clay was opened up, but found to be of uncertain quality.[b] At Clearfield, east of the railroad station at the north end of the town, the fire clay showed a curious local thickening, but a later examination showed that the bed had so diminished or changed in purity that the mine was abandoned. At Benezette, in the third coal basin, fire clays occur immediately on top of the Pottsville conglomerate, notably from a point one-half mile above Benezette up to Trout Run, a distance of 2½ miles. It showed from 3 to 7 feet of hard clay.[c] Another occurrence was 2 miles west of Benezette.

At Brookville, Jefferson County, the coal is underlain by a bed of fire clay 15 or more feet thick, as shown by the following section from Redbank Creek, south of Brookville.[d]

Section at Brookville, Jefferson County, Pa.

	Feet.
Hill top.	
Shaly slates	25
Coal	2–3
Fire clay	15 or more.
Concealed (sandstone)	120

At the time the report referred to was written the upper 6 feet were worked. The composition is shown by Nos. 15, 16, and 17 in the table on page 220. The clay has been mined at Newsome, and while of the same age probably as the clays at Blueball, Sandyridge, and Woodland, it carries a higher percentage of silica, as a comparison of the analyses will show.

In Mercer County the Brookville coal is underlain at many points by several feet of fire clay.[e]

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[a] Second Pennsylvania Geol. Survey, Rept. H, pp. 120 and 121.
[b] Ibid., p. 124.
[c] Ibid., p. 134.
[d] Ibid., p. 225.
[e] Idem, Rept. Q3, pp. 27, 81, 111, 134, etc.

Analyses of Brookville under clays.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	45.42	45.65	44.95	45.82	74.95	42.7	43.35	44.55	46.25	45.45
Al_2O_3	36.80	34.73	37.75	35.95	15.94	37.6	37.55	39.00	37.50	36.125
Fe_2O_3	3.33	3.546	2.70	3.33	1.899					
FeO						2.385	2.145	1.44	1.935	2.275
MnO_2	.48									
CaO	.87	.112	.302	.112	.106	.112	.084	.028	.168	.168
MgO	.45	.619	.216	.573	.407	.270	.234	.072	.126	.342
Alk		5.75	.985	4.13	1.756	.73	.235	.53	1.115	1.29
H_2O / Org	12.65	9.65	13.05	10.13	4.885	13.84	14.17	13.66	13.54	13.73
LiO_2						2.50	2.825	1.70		
SO_3										
FeS_2										

	11.	12.	13.	14.	15.	16.	17.	18.	19.
SiO_2	45.23	46.18	44.45	44.045	58.125	60.675	78.075	64.83	68.49
Al_2O_3	38.03	36.88	38.945	39.445	26.5	25.915	14.44	23.95	18.46
Fe_2O_3	1.98	2.25							
FeO			2.135	.94	3.234	2.21	1.59	.9	1.566
MnO_2									
CaO	.163	.173	.173	.075	.078	.089	.056	.11	.23
MgO	.237	.317	.155	.115	.555	.465	.48	.187	.551
Alk	.830	2.76	.76	.72	2.18	1.925	1.67	.296	2.755
H_2O / Org	13.605	11.58	13.287	14.138	9.725	9.09	4.163	9.39	6.31
LiO_2								.88	2.15
SO_3			Tr.	Tr.	.058	Tr.	Tr.		
FeS_2					.008				

1. Fire clay, Johnstown, Cambria County. Second Pennsylvania Geol. Surv., Rept. HH, p. 147.
2. Fire clay, Sandy ridge, Clearfield County. Top layer used for furnace bottoms.
3. Second layer, same locality. Used for bricks.
4. Third layer, same locality. Used for tiles and inwalls of furnace.
5. Bottom layer, same locality. Sandy and not used; 2 to 5 feet thick. Idem, Rept. H, p. 119.
6. Upper or "Shell clay" from shaft of Harris Firebrick Company, 2½ miles west of Blueball. Ibid., p. 121.
7. Middle or Black clay, same place. Ibid.
8. Lower or "Flag clay," same locality; 6 to 8 feet. Ibid.
9. From south side of Roaring Run Brook, near Woodland station. Ibid., p. 123.
10. North side of Roaring Run Brook, three-fourths mile west of Woodland station. Bed 4 to 5 feet hard clay. Ibid., p. 123.

11. Hard clay, one-half mile southeast of Hope mine. Ibid., p. 124.
12. Soft clay, one-half mile southeast of Hope mine. Ibid.
13. Fire clay from Jones mine, between Benezette and Trout Run, Lycoming County. Ibid., p. 134.
14. Hard fire clay, E. Fletcher & Brother, 2 miles west of Benezette. Ibid., p. 135.
15. }
16. } Fire clay, Newsome. Ibid., p. 225.
17. }
18. Upper clay }
19. Plastic clay } Blacklick, Indiana County. Idem, Rept. H4, p. 194.

CLARION COAL UNDER CLAY.

Below the Clarion coal there is a bed of fire clay which seems to be good at nearly all the localities where it is exposed, and which has been used at Bolivar for fire brick.[a] A large bed of fire clay from 7 to 10 feet thick, the lower part being nonplastic, underlies Clarion coal along Big Beaver.[b] The Brush Creek coal is underlain by fire clay in several places in Butler County, notably in Cranberry and Adams townships, also Middlesex Township. Again, on the north and east side of the Youghiogheny River, at Ohiopyle, and thence along the road leading to Springfield, the fire clay occurs above the Clarion coal bed.[c] The Clarion clay has also been mined by the Fallston Pottery Company, Beaver County, on the east side of Bradys Run[d], where it is 10 to 12 feet thick. The same clay is also exposed in the bottom of Pine Run near the Enterprise Pottery.[e]

An important deposit of fire clay occurs near top of shales between Brookville and Clarion coal, at a point 1 mile northeast of Kittanning. The clay seems to be of local importance, and not noticeable elsewhere.[f] It is semiplastic and averages 5½ feet. A general section is given. Its composition is as follows:

Analysis of fire-clay deposit between Brookville and Clarion coal.

Silica	58.75
Alumina	25.17
Iron protoxide	2.195
Manganese, oxide of	Trace.
Titanic acid	1.05
Lime	.71
Magnesia	.936
Alkalies	3.535
Water	8.110
Total	100.456

[a] Second Pennsylvania Geol. Survey, Rept. K3, p. 43.
[b] Idem, Rept. Q, p. 63.
[c] Idem, Rept. K3, p. 94.
[d] Hopkins, Clays of Western Pennsylvania, p. 31.
[e] Ibid., p. 32.
[f] Second Pennsylvania Geol. Survey, Rept. H5, p. 245.

The thickness of the Clarion at several localities in Pennsylvania is as follows:

Thickness of Clarion clay in Pennsylvania.

	Ft.	In.
Johnstown, Cambria County	3	6
Bens Run, Cambria County	6	0
Pinkerton Point, Somerset County	6	0

FERRIFEROUS COAL UNDER CLAY.

A deposit of fire clay is found between the Ferriferous coal bed and the Buhrstone iron ore in Armstrong County,[a] and is found in workable quantity near Allegheny Furnace, and also at Kittanning. To the north it seems to be replaced by shale. The clay is both hard and semiplastic. The latter analyzed gives:

Analysis of clay under Ferriferous coal.

Silica	50.370
Alumina	32.890
Iron protoxide	1.641
Titanic acid	1.030
Lime	.310
Magnesia	.353
Alkalies	.290
Water and organic matter	13.760
Total	100.644

Another deposit has been opened under the Ferriferous coal near Mineral Spring, at Kittanning.[b] It is overlain by a considerable thickness of shales, which may at times replace it. The composition of the fire clay is:

Analysis of fire clay near Mineral Spring, at Kittanning, Pa.

Silica	55.96
Alumina	28.415
Iron protoxide	1.641
Titanic acid	1.01
Lime	.07
Magnesia	.396
Alkalies	.615
Water and organic matter	12.690
Total	100.797

LOWER KITTANNING FIRE CLAY.

The Kittanning fire clay is one of the most valuable refractory plastic deposits found in Pennsylvania. It occupies a well-marked position under the Lower Kittanning coal, and is sometimes called the New Brighton fire clay[c] (fig. 7). Folding

[a] Second Pennsylvania Geol. Survey, Rept. H5, p. 239.
[b] Ibid., p. 249.
[c] Clays of western Pennsylvania: Ann. Rept. Pennsylvania State College, 1897, p. 53.

of the rocks and subsequent erosion have exposed it at a number of localities, and outcrops of it are known and worked in Beaver, Armstrong, Fayette, Westmore-Clarion, and Jefferson counties. The following notes regarding its occurrence are taken chiefly from the special reports of the Second Pennsylvania Geological Survey.

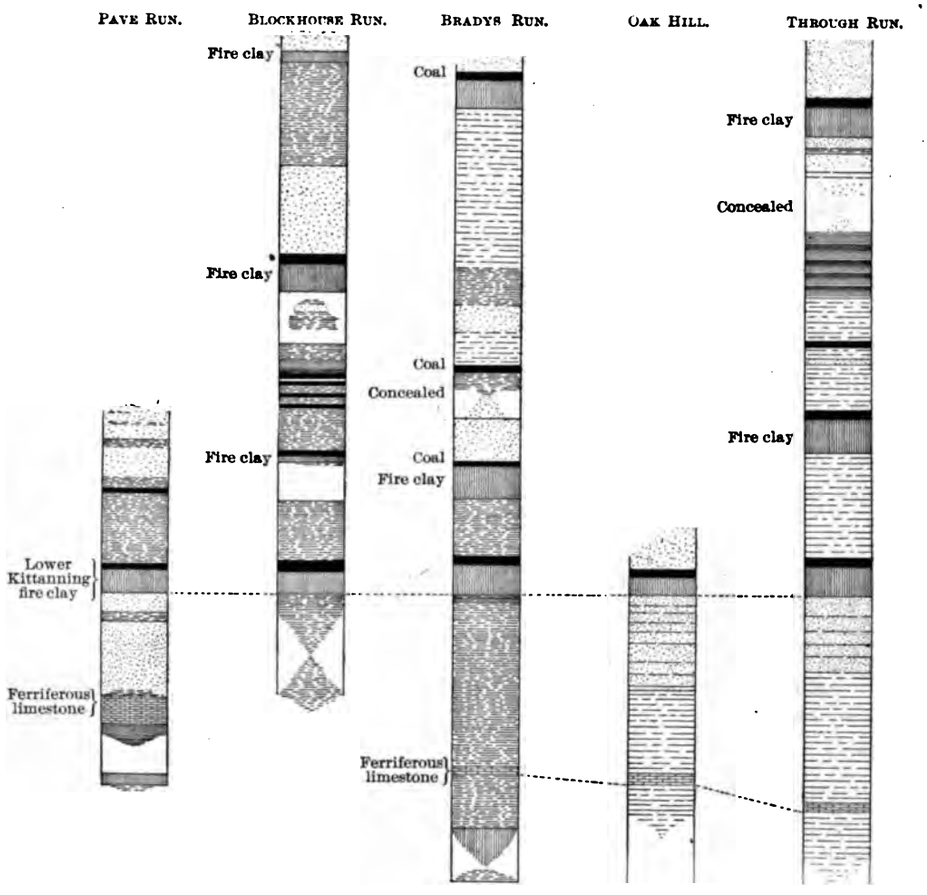

Fig. 7.—Section showing Lower Kittanning fire clay in western Pennsylvania (after Hopkins).

At times it does not immediately underlie the coal, but may be found as low as the top of the Ferriferous limestone. It is best developed west of the Allegheny River,[a] attaining its maximum development along the Beaver River and westward from that stream down the Ohio.

[a] Bulletin U. S. Geol. Survey No. 65, p. 171.

The thickness of the Lower Kittanning fire clay at several localities in Pennsylvania is as follows:

Thickness of Lower Kittanning fire clay in Pennsylvania.

Locality.	County.	Thickness.
		Feet.
Beaver Run	Westmoreland	25
Bennington	Blair	3
Carpenters Station	Westmoreland	12
Fall Brook	Tioga	3
Kittanning	Armstrong	5
Putneyville	do	[a]6
Sewickley	Allegheny	8

[a] Impure.

Armstrong County.—The Kittanning fire clay is exposed at several points in this county, but at no locality forms a bed of great importance.[a]

Beaver County.—The Kittanning clay is found in nearly every part of the county, and forms the basis of an important fire-brick industry.[b] The bricks are not of the most refractory character, but are especially adapted to those parts of the furnace where resistance to abrasion is required. The clay is rarely less than 10 feet thick, and may reach 15 feet, but the lower 6 to 7 feet are usually too siliceous. It has been mined in the townships of Ohio,[c] New Sewickley (Freedom),[d] Marion,[e] Pulaski,[f] and Rochester.[g]

The Lower Kittanning clay is used between Rochester and Brighton by Ingraham & Co.; also at Conway by G. Dando & Brother. Here it is 8 feet thick. This clay bed supplies nearly all of the potteries, hollow-ware, fire-brick, and paving-brick factories at New Brighton and vicinity. In 1897 it was mined at Crows Run, near Freedom, at Monaca and Vanport, and below Beaver, on the north side of the Ohio River; also opposite Beaver, and on Bennetts Run, above New Brighton. It is probably continuous to Ohio, but west of Vanport dam the drift covering is said to be too heavy to permit its being profitably mined.[h] The thickness of the clay deposit is rather uniform in the Beaver Valley region, but the thickness of bed worked varies according to the kind of ware to be made from it, some manufacturers being able to use a larger proportion of the sandy layers than others. The thickness worked at several localities is as follows:[i]

[a] Second Pennsylvania Geol. Survey, Rept. H5, Armstrong County.
[b] Idem, Rept. Q, pp. 58, 59.
[c] Ibid., p. 265.
[d] Ibid., p. 190.
[e] Ibid., p. 215.
[f] Ibid., p. 195.
[g] Ibid., p. 193.
[h] Clays of western Pennsylvania: Ann. Rept. Pennsylvania State College, 1897, p. 33.
[i] Ibid.

Thickness of Lower Kittanning clay at various points.

	Feet.
Sherwood Bros	7
Enterprise Pottery Company	8
Sewer-pipe works	6–7
A. F. Smith & Sons	6–7
Ingram & Co	7–8
Welch, Gloniger & Co., Monaca	6
Bradys Run Fire Brick Company, Monaca	16
Stahl Fire Brick Company, Beaver	6
Park Fire Clay Company, Mahan	10–12

The clay is often weathered before being used.

Fayette County.—In Springhill Township a bed of good fire clay occurs from 15 to 20 feet below the Kittanning coal, and has been used for fire brick. It is usually free from iron, but pockets of ore occur occasionally and may replace the clay for a short distance.

Westmoreland County.—The fire clay usually found is a plastic clay from 5 to 7 feet thick.[a] It may at times be gritty, as in Cook and Ligonier townships.

Analyses of Kittanning lower coal under clay.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
SiO_2	61.970	61.750	62.890	62.260	66.610	56.670	57.670	60.190	61.980
Al_2O_3	22.940	23.660	21.490	23.890	18.390	26.560	27.520	24.230	23.880
FeO	1.818	1.930	1.818	1.408	1.964	2.106	1.494	2.097	1.395
TiO_2	1.975	1.780	1.825	1.780	2.810	1.790	2.540	2.345	1.830
CaO	0.440	0.455	0.380	0.470	0.490	0.260	0.380	0.850	0.040
MgO	0.522	0.353	0.569	0.309	0.547	0.277	0.122	0.036	0.281
Alkalies	1.750	2.418	2.525	1.977	1.079	3.790	0.619	1.669	1.217
H_2O (hygroscopic)	1.480	0.680	1.160	7.640	7.495	8.360	9.680	9.015	1.460
H_2O (combined)	7.370	7.200	7.580						7.820
Total	100.265	100.226	100.237	99.734	99.385	99.813	100.025	100.432	99.903
Sand	34.250	.....	35.510	.....	.....	.....	.....	.....	.....
SiO_2 in sand	34.180	.....	35.100	.....	.....	.....	.....	.....	.....

1 to 4. From Elverson & Sherwood's mines, near New Brighton, Beaver County, being, respectively, first, second, and third grades of clay and the raw clay. Second Pennsylvania Geological Survey, Rept. MM, p. 262.

5. Mandon, Hall, and Chamberlain mines, near New Brighton, Beaver County. Ibid.

6. Coale's clay, near New Brighton, Beaver County. Ibid.

7. Couche's clay, New Brighton, Beaver County. Ibid.

8. Severn's clay mines, near Vanporte, on Ohio River, New Brighton township, Beaver County. Ibid.

9. S. Barnes & Co.'s clay, near Bridgewater, 1 mile north of Rochester, Beaver County. Ibid.

[a] Second Pennsylvania Geol. Survey, Rept. K3, p. 40.

MIDDLE KITTANNING CLAY.

This may, at times, be underlain by fire clay, as seen in the section at Ore Hill Furnace, Armstrong County, where a bed 2 feet 6 inches thick is found.[a] The Lower Kittanning is found in the same section.

The thickness of the Middle Kittanning in Pennsylvania is as follows:

Thickness of Middle Kittanning clay in Pennsylvania.

Locality.	County.	Depth.
		Feet.
Beaver River	Beaver	[a]3
Bennington	Blair	[b]6
Blossburg	Tioga	3
Kittanning	Armstrong	4
Logansport	do	8
Sewickley	Allegheny	8

[a] Plus 40-foot shales. [b] Impure.

UPPER KITTANNING CLAY.

This underlies the Freeport sandstone, a bed of shale lying between. Under it is a fire clay of very good quality.[b]

LOWER FREEPORT CLAY.

This underlies the Lower Freeport coal at several localities at Frostburg,[c] and is of proper quality for potters' use.

UPPER FREEPORT OR BOLIVAR FIRE CLAY.

This is a bed of nonplastic or flint clay, nad is one of the most valuable of the refractory deposits found in western Pennsylvania, where it is also very extensively worked. It gets its name from the fact that it is best developed at Bolivar, at the eastern end of the Conemaugh Gap through Chestnut Ridge. Stratigraphically it lies near the top of the Lower Productive series, being immediately under the Upper Freeport limestone, but a similar clay, which is sometimes confused with it, appears directly below the Upper Freeport coal bed.[d]

While the Bolivar clay is widely distributed, at the same time it is not found at every one of the localities where its horizon is reached, and its place is sometimes taken by a less refractory shale. At the type locality at Bolivar it is from 20 to 25 feet thick, according to T. C. Hopkins, but it is said to vary greatly throughout the region of the western slope of Chestnut Ridge and the Ligonier Valley.

[a] Bull. U. S. Geol. Survey No. 65, p. 107, fig. 60.
[b] Second Pennsylvania Geol. Survey, Rept. Q. p. 265.
[c] Idem, Rept. H6, p. 16.
[d] Second Pennsylvania Geol. Survey, Rept. K3, p. 34; and The clays of western Pennsylvania: Ann. Rept. Pennsylvania State College, 1897, p. 53.

The counties from which occurrences of this clay have been described are Allegheny, Armstrong, Beaver, Butler, Fayette, Indiana, Somerset, and Westmoreland.

The thickness of the Upper Freeport at various localities is given below.

Thickness of Upper Freeport or Bolivar fire clay in Pennsylvania.

Locality.	County.	Thickness of fire clay.	
		Ft.	*In.*
Bens Creek	Cambria	6	0
Carpenters Station	Westmoreland	[a]65	0
Horton Township	Elk	[b]5	0
Near Johnstown	Cambria	[c]40	0
Karthaus	Clearfield	2	6
	Clarion	5	0
Morrisdale	Clearfield	[a]32	6
Putneyville	Armstrong	[a]12	0
Sewickley	Allegheny	15	6

[a] Includes shales. [b] Includes sandstone. [c] Fire clay and sandy shales.

Allegheny County.—The Bolivar clay forms a bed 3 feet thick on Gourdhead Run, Hampton Township, as well as at several other points.[a]

Armstrong County.—The Upper Freeport fire clay is said to be of importance at Salina, but seems to fade out in a westerly direction down the river. It contains occasional small lenses of iron ore.[b] At Apollo, it is exposed underneath the limestone, and there are said to be 8 feet of it, of somewhat impure character, at Leachburg.[c] It is also well exposed at the top of the hill south of the rolling mill at Bradys Bend and at Templeton. The clay has also been mined near Manorville,[d] and may occur in the Cowanshannock region.[e]

Beaver County.—In Big Beaver Township the Freeport clay has been extensively mined and made into fire brick. It ranges in thickness from 2 to 10 feet, but may be replaced at times by limestone and iron ore, as at Adams.[f]

Butler County.—The Freeport upper coal is underlain by 4 feet of excellent fire clay, especially mentioned as occurring in Winfield Township at the Collins bank.

Fayette County.—In Fayette County the Bolivar clay has been reported from the following localities: In Wharton Township, near Wharton furnace, where it is 10 feet thick, with nodules of clay ironstone; in Stewart Township, forming a bed 8 feet thick along the river hills and containing balls of iron ore; on Indiana Creek, Springhill Township, with a thickness of 4 feet; 2 miles north of Ohiopyle village.

[a] Second Pennsylvania Geol. Survey, Rept. Q, p. 158.
[b] Idem, Rept. H5, p. 14.
[c] Ibid., p. 26.
[d] Ibid., p. 252.
[e] Ibid., p. 89.
[f] Idem, Rept. Q, p. 224.

At Baylies Point the flint clay is 12 to 15 feet thick and is overlain in places by 2 to 4 feet of plastic clays. Another occurrence is 2½ miles east of Moir. The Bolivar clay is also mined near Layton station, that quarried 1 mile east of the station being used for the manufacture of glass pots. It is here from 4 to 6 feet thick; the clay is carefully selected by hand, the rejected portions being used for fire brick.

Indiana County.—The clay has been mined at many localities in this county and varies from 3 to 6 feet in thickness. It is said to be usually of good quality and comparatively free from impurities.[a] A specially large deposit of it is known to occur at Bells Mills.[b] Professor Stevenson[c] reports the clay from a number of localities in the Ligonier Valley south of the Conemaugh River, and states that it forms quite a persistent stratum in Fayette County, being traceable across the Youghiogheny into West Virginia.

Analyses of both the hard and soft clay show much TiO_2.

Westmoreland County.—The Upper Freeport clay forms the center of an active clay-working industry at Bolivar, but is also worked at several other points.

The following general section at Bolivar is given by Stevenson:[d]

Section at Bolivar, Pa.

	Feet.	Inches.
Mahoning sandstone	20	0
Clay	0	3–6
Upper Freeport coal bed	8	9
Drab fire clay	3	0
Sandstone	2	0
Clay, with iron ore	3	0
Coal bed	0	4
Clay and shale	30	0
Sandy shale	25	0
Fissile shale	30	0
Lower Freeport coal bed	1	5
Clay and shale	6	0
Limestone	3	0
Dark shale	35	0
Shale	10	0
Upper Kittanning coal bed	1	6
Fire clay	1	6
Upper Kittanning limestone	1	6
Concealed	47	0
Sandstone	40	0
Shale	12	0
Clarion coal bed	1	6
Fire clay	2	0
Concealed	25	0

[a] Second Pennsylvania Geol. Survey, Rept. H4, p. 89. [b] Ibid., p. 184. [c] Ibid., p. 90. [d] Idem, Rept. K3, p. 158.

Section at Bolivar, Pa.—Continued.

	Feet.	Inches.
Shale	20	0
Concealed	35	0
Brookville coal bed	Blossom.	
Shale	15	0
Pottsville conglomerate	--	--
Total thickness	380	0

Hopkins[a] says that while this gives a good idea of the general succession of the beds, still the thicknesses noted do not agree with those observed in the present workings, being in most cases too small. The following statement regarding these fire clays in the vicinity of Bolivar is an abstract of the description in his report:

The Bolivar clay varies greatly in thickness, ranging from 6 to 25 feet at different points in the State. On the south side of the river it has been mined extensively over a large area on the King tract, about half a mile southeast of Bolivar, on the slope east of Tub Mill Creek, near the base of the ridge. The clay here is 18 to 20 feet thick and is worked by open pits. Ore balls are very abundant in certain spots, but seem to favor the upper layers rather than the lower ones, and in mining they can be, and are, picked out. The Bolivar flint clay is also mined on the property of the Lincoln Company, showing there 18 to 20 feet overlain by 8 feet of shale and soapstone, followed by 6 feet of coal. The upper 6 to 8 feet are often called black clay and are thought to be superior. On the northeast side of the Conemaugh River, in Indiana County, but opposite Bolivar, the upper clay bed has been worked at a number of places, 22 feet of flint clay being exposed at one point. An old flint-clay mine on the northeast side of the river is known as the Garfield flint clay, and is 1 mile east of Bolivar. The flint clay is also worked near the top of the ridge on the south side of Roaring Run. There is said to be a higher bed of flint clay known as the Upper Bolivar flint clay, and found on the hilltops in the form of remnants or pots. It is said to be highly refractory, but is not worked on account of its scarcity. Below the Bolivar clay is a bed of plastic fire clay, the interval between the two being 200 feet. It is mined on the south side of the river, near the mouth of Tub Mill Creek, and also on the north side of the river, in the hill below the flint mine No. 3 of Reese, Hammond & Co. This bed really consists of two beds, known locally as the upper soft clay and the lower clay. In one mine the material between the two layers is sufficiently thin to permit working them together. In the other mines only the upper portion of the clay, from 6 to 8 feet thick and lying above the separating sandstone, is worked. This clay bears an excellent reputation and is rather plastic. Another bed is said to exist between this clay and the flint clay overlying, and one or two beds of plastic clay are also stated to occur at a lower

[a] Clays of western Pennsylvania: Ann. Rept. Pennsylvania State College, 1897, p. 77.

horizon; but the test of one of these lower beds has shown that it is much less refractory.

Where high refractoriness is desired, it is said that some clay is brought to Bolivar from South Fork, Blueball, and Moshannon, in Clearfield County. The Bolivar clay will make a more plastic and porous brick than many other clays of greater refractoriness.[a]

In addition to the workings at Bolivar, the clay is also said to occur northward from Loyalhanna, on the west side of the valley, extending from the southern boundary of Fairfield Township to the Conemaugh Valley.[b]

At Salina the Bolivar clay dips eastward and varies in thickness from 6 to 13 feet, including both the flint clay and the soft plastic fire clay. There is no regularity of distribution of the two, however, in the same bed.

In the following table are given a number of analyses of the Bolivar fire clay:

Analyses of Bolivar or Freeport upper coal under clay.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	59.830	51.920	47.250	40.720	60.520	55.330	55.680	56.780	65.370	52.230
Al_2O_3	24.580	31.640	34.350	37.280	24.970	27.841	29.180	26.890	24.870	31.310
FeO	1.655	1.134	0.693	2.448	1.650	2.916	0.837	0.322	0.756	1.008
TiO_2	1.170	1.160	1.990	2.280	1.220	1.140	1.490	Not determined.		1.680
CaO	0.280	0.030	0.580	0.520	0.910	0.580	0.130	0.369	0.168	0.130
MgO	0.872	0.443	0.090	0.002	Trace.	0.756	0.180	0.987	0.234	0.165
Alkalies	3.114	0.402	0.261	0.570	0.218	3.916	0.245	3.920	0.010	0.720
Water	7.830	13.490	13.695	15.002	9.395	7.495	12.490	8.380	8.790	13.190
CO_2	.....	None.	0.455	0.408	0.725	0.455	.....	.....	.....	.....
Total	99.331	100.219	99.364	99.230	99.608	100.429	100.232	100.548	100.378	100.433

1. E. Robinson's clay deposit in Indiana County. Second Pennsylvania Geol. Survey, Rept. H4, p. 90.

2. Kier Brothers, Salina, Bell Township, Westmoreland County; flint clay. Idem, Rept. H5, p. 14.

3. Kier Brothers' clay, Salina; top stratum, hard and brittle. Ibid.

4. Kier Brothers' clay, Salina; middle stratum, hard and brittle. Ibid.

5. Kier Brothers' clay, Salina; bottom stratum. Ibid.

6. Kier Brothers' clay, Salina; plastic clay. Ibid.

7. R. Hall's, near Laughlinstown, 4 miles east from Ligonier, Westmoreland County. Idem, Rept. K3, p. 249.

8. Furnace clay on Jacobs Creek, 2 miles southeast of Jacobs Creek station. Idem, Rept. L, p. 112.

9. Forge clay on Jacobs Creek, 2½ miles southeast of Jacobs Creek station. Ibid.

10. George Potter's clay on Meadow Run, south of Ohio Pyle Falls, Fayette County. Idem, Rept. K3, p. 249.

[a] Clays of western Pennsylvania, p. 80.

[b] Second Pennsylvania Geol. Survey, Rept. K3, p. 34.

BARREN MEASURES OR ELK RIVER GROUP.

The Barren Measures or Elk River series consist largely of shales and sandstones, with some limestones, the shales predominating in the upper beds of the section and the sandstones in the lower (fig. 8).

The general character can best be told from a glance at the accompanying section (fig. 8) taken from I. C. White's bulletin[a] already referred to.

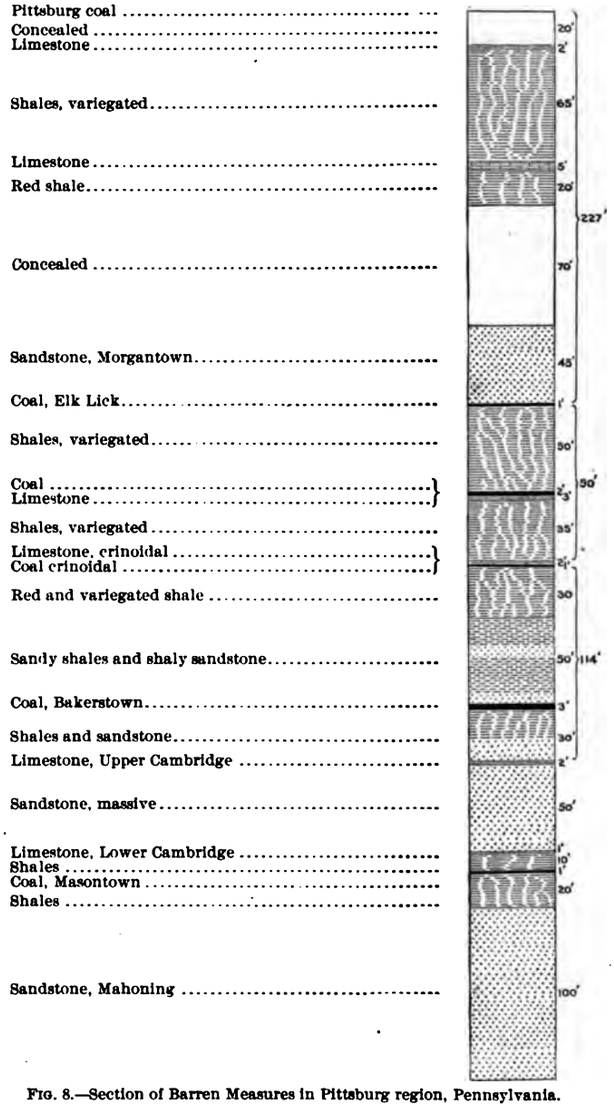

FIG. 8.—Section of Barren Measures in Pittsburg region, Pennsylvania.

[a] Bull. U. S. Geol. Survey No. 65, p. 72.

In Allegheny County the Lower Barren Measures constitute the greater part of the surface rocks, all of the northern half of the county, with the exception of small areas of Upper and Lower Productive Measures, and about one-half of the southern part being covered by them. Hopkins gives the following section:

Section of Lower Barren Measures in Allegheny County, Pa.

		Feet.
1.	Pittsburg coal bed.	
2.	Fire clay	3
3.	Shale	10
4.	Limestone	6
5.	Coal bed	1
6.	Shale	25
7.	Limestone	3
8.	Shale	10
9.	Coal bed	1.5
10.	Limestone	5
11.	Connellsville sandstone	60
12.	Shale	35
13.	Coal bed	1
14.	Limestone	4
15.	Morgantown sandstone	50
16.	Clay	9
17.	Barton coal bed	1
18.	Shale	36
19.	Crinoidal limestone	4
20.	Shales and clays	100
21.	Coal bed	2
22.	Shale	60
23.	Black limestone and shale	4
24.	Shale and shaly sandstone	35
25.	Coal bed	2
26.	Shale	30
27.	Mahoning sandstone.	
	Total	491.5

Affelder[a] states that at Pittsburg, where 320 feet of strata of the Lower Barren Measures are exposed between the level of the Monongahela River and the outcrop of the Pittsburg coal near the hilltop, almost all of the rock is shale. So enormous are the deposits of shale that the manufacture of brick can be carried on for centuries without materially diminishing the amount; but abundant as the shales are, they do not vary greatly in their general characteristics. Nearly all of them, with the exception of the very arenaceous, are well adapted to the manufacture of brick, and they all show evidence of the presence of iron to a greater or less degree. In some the

[a] The Clays of western Pennsylvania: Ann. Rept. Pennsylvania State College, 1897, p. 137.

prevalent state of the iron is the ferrous, while in others it is the ferric, but the majority are stained with ferric iron, especially after they have been subjected to the action of the atmosphere. By far the most common variety of the shale is the yellowish, slightly arenaceous one, which grades at the surface to a sandy clay, and, as the depth increases, to a more or less impure sandstone. Bluish shales are common in some localities. Some of them are so argillaceous and so distinctly laminated as to look very much like slate, but the majority of them are shelly and readily disintegrate to small flakes. In color they vary from slate to bluish gray. Recently M. Lanz & Sons, of Pittsburg, have experimented with a bluish shale which occurs under the shale deposit from which they obtain their material for making red brick, and have succeeded in making a buff brick of good color and quality for building purposes. Greenish shales containing much ferrous iron occur less frequently than the blue, and they are always badly discolored as a result of atmospheric action. Red shales are not very abundant, but where they do occur they have generally disintegrated on the outcrop to a red clay.

Fire clays are not abundant in this county, and even where found they are too impure to be used for making fire brick, although in some localities these clays are used to advantage in making building or paving brick. At Harmarville an excellent reddish-buff repressed brick is made from a 10-foot vein of such clay. The presence of a small amount of iron prevents uniformity in color, and the brick are adapted only to paving. At Briggston a very hard building brick is made from an impure fire clay mixed with hard shale.

A thriving clay-working industry exists in Allegheny County, and of 57 yards listed in Hopkins's report over two-thirds use shale wholly or in part.

The product consists chiefly of red brick, but some paving and pressed brick also are manufactured.

UPPER COAL MEASURES, OR MONONGAHELA RIVER GROUP.

These have their greatest development in southwestern Pennsylvania, and while the shale deposits are not so abundant as in West Virginia, still occasional beds of good thickness occur.

An important clay is that found as a persistent parting in the Pittsburg coal, and it is used in the Monongahela Valley. The clay is not more than 6 to 10 inches thick, but has to be removed in mining the coal, hence it is profitable to use it. This bed of clay is said to be wonderfully persistent throughout the entire area of the Pittsburg coal bed, and Hopkins comments on the fact that it has not been used at other places, for there are vast quantities piled up around numerous mines over southwestern Pennsylvania. This clay is used in part for fire brick. The same clay—horseback," or clay parting—is worked at Fayette City. The shale over the coal is

used for making red brick, the section involved in Dinsmore Brothers' quarry being as follows:[a]

Section at Dinsmore quarry, Fayette City, Pa.

	Feet.
Shale quarried for brick	35
Shale not quarried, partly concealed	20
The Pittsburg coal seam and clay parting	9
Shale	10
Limestone and shale	10
Shale	8

A section of the Upper Productive Measures, after I. C. White, is given in fig. 9.

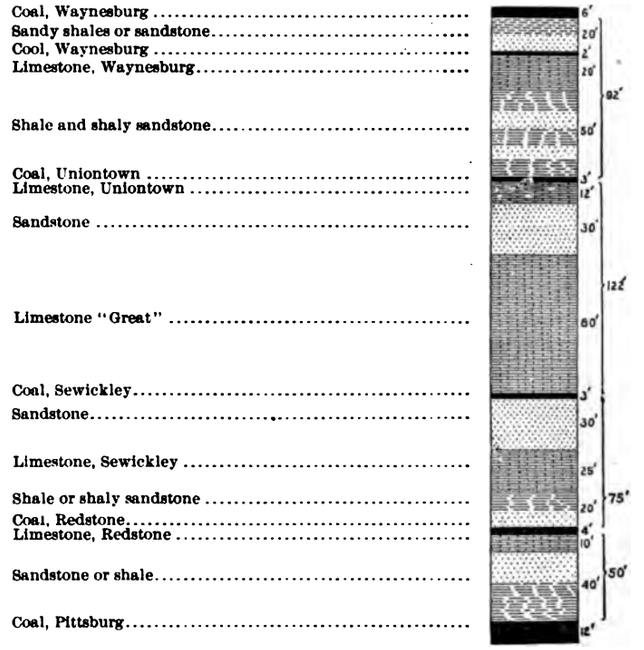

FIG. 9.—Section of Upper Productive Measures in Fayette and Westmoreland Counties, Pa.

At Pittsburg shale of the Upper Coal Measures is used for making common brick at several different yards. The Pittsburg Terra Cotta Lumber Company, at Pittsburg, also uses shale, but mixes it with surface clay. Its composition is given below:

[a] Ann. Rept. Pennsylvania State College, 1897, p. 132.

Analysis of shale from Upper Coal Measures, near Pittsburg, Pa.

SiO_2	57.537
Al_2O_3	20.127
FeO	5.797
$CaCO_3$, $MgCO_3$, Alk by difference	9.022
H_2O and organic matter	7.517
Total	100.00

At the quarry of the American Clay Manufacturing Company a section shows:[a]

Section at quarry of American Clay Manufacturing Company, Pittsburg, Pa.

	Feet.
Sandy yellow clay	3
Thinly bedded arenaceous shale	8
Poor sandstone	2
Clay	30

SURFACE, OR PLEISTOCENE CLAYS.

These may occur in all parts of the State, more especially along the larger lines of drainage. They are found existing under several conditions, viz, as terrace deposits, basin deposits, or morainal clays.

The terrace deposits usually underlie the terraces bordering the rivers, and often represent the fine clay and silt deposited during recent or remote periods of high water. The former would be found near the present river level, the latter often many feet above it.

The basin deposits are chiefly to be looked for north of the terminal moraine of the Glacial epoch, and represent the fine clay deposited in valleys whose streams have become dammed up and converted into ponds or lakes.

The morainal deposits are clays of irregular occurrence found at times in the terminal moraine, and may often be stony.

The surface clays are usually impure and frequently sandy, and are consequently chiefly adapted to the manufacture of common brick, although pressed brick and even pottery are made from them in cases where the clays are finer and more homogeneous. In the Carboniferous areas, where shale outcrops are often abundant, the latter are sometimes mixed with the surface clays, producing excellent results. In the western part of the State they are abundant along the Allegheny, Monongahela, Beaver, Ohio, and Youghiogheny. References to these have been made in Hopkins's report on the clays of western Pennsylvania and in the several county reports of the Second Pennsylvania Geological Survey.

[a] Ann. Rept. Pennsylvania State College, 1897, p. 144.

The valleys of the Ohio and Beaver rivers are filled with glacial drift, and the terraces bordering them are underlain by clay.[a] An important deposit has been worked in the fourth terrace at New Brighton. This deposit, which was used for making terra cotta, shows the following composition:[b]

Analyses of terrace clay at New Brighton, Pa.

Constituents.	Mendenhall & Chamberlin.	Elverson & Sherwood.
Silica	46.160	67.780
Alumina	26.976	16.290
Sesquioxide of iron	7.214	4.570
Titanic acid	.740	.780
Lime	2.210	.600
Magnesia	1.520	.727
Alkalies	3.246	2.001
Water	11.220	6.340
Total	99.286	99.088

This same clay has also been successfully employed in the manufacture of flower pots.

In Allegheny County the alluvial clays along the rivers are used for making building brick at about 10 per cent of the yards. These clays are obtained from river flats which border on the Ohio, Allegheny, Monongahela, and Youghiogheny rivers. Some of them are said to be flood-plain deposits. Terrace clays are abundant in the vicinity of many rivers, especially in and near Pittsburg. In the Monongahela Valley surface clays are used at several localities for the manufacture of brick, among them Leetsdale, Braddock, and Wilkinsburg. At some of these places the clay is mixed with shale. Surface clays are also worked in the Youghiogheny Valley at Connellsville for building, paving, and pressed brick;[c] at West Newton, in the same valley, the alluvium is worked to a depth of 8 or 10 feet, or even 15 feet. In the Monongahela Valley many brick are made from surface clays, as at Monongahela City and Charleroi, in Washington County. At this last place the section is as follows:

Section at Charleroi, Washington County, Pa.

	Feet.
Surface clay	2– 3
Shelly sandstone	4–10
Yellow clay	4– 5
Red clay	15–20

[a] Second Pennsylvania Geol. Survey, Rept. Q, pp. 10, 11, 12.
[b] Idem, Rept. MM, p. 257.
[c] Ann. Rept. Pennsylvania State College, 1897, p. 128.

The composition is as follows:[a]

Partial analysis of surface clay at Charleroi, Washington County, Pa.

Silica	56.32
Alumina	21.44
Iron oxide	9.92
Loss on ignition	6.73
Total	96.41

Alluvial clays are also worked for common and pressed brick at Freeport, Armstrong County; Sheridan, Lebanon County; Hyde Park, Ligonier, and Mount Pleasant, Westmoreland County; Uniontown, Dawson, Smithfield, and Fairchance, Fayette County; and California, Washington County.

At Dawson the section involves:

Section at Dawson, Pa.

	Ft.	Ins.
Clay	14	0
Iron ore	0	14
Blue clay	12	0

In the Allegheny River Valley several brick yards in the vicinity of Allegheny use the surface clays for mixing with the Carboniferous shales. Most of the swamps in McKean County are said to be underlain by clays which are sometimes refractory in character.[b] In Perry County common brick clay exists at many points, especially near New Bloomfield, where there is a deposit of alluvial clay of a fine white color.[c] In Pike and Miner counties surface clay suitable for the manufacture of pottery occurs on the land of T. Bells, 2½ miles below Ledgedale, on the Old Valley of the Paupack, and has been manufactured into red ware. The section involves:[d]

Section near Ledgedale, Pa.

	Feet.
Clay soil	1½– 2
Gray clay (full of roots)	15 –20
Very sandy clay	2
Total	24

Another deposit occurs on the opposite or Wayne County side of the Paupack, 200 feet above the stream level. It is said to be 200 feet thick.

In Harmony Township, Susquehanna county,[e] I. C. White states that the old channel of Starrucca Creek has been filled up by 75 feet of impervious reddish-drab clay of glacial origin. It has been used in the manufacture of brick, and 40 feet of it were exposed in a railroad cut. Other deposits of glacial clay occur at Williamsport, Hughesville, and other points in Lycoming County.[f]

[a] Am. Rept. Pennsylvania State College, 1897, p. 131.
[b] Second Pennsylvania Geol. Survey, Rept. R, p. 28.
[c] Idem, Rept. FF, 208.
[d] Idem, Rept. G6, p. 170.
[e] Idem, Rept. G5, p. 97.
[f] Idem, Rept. Z, p. 136.

Clays for building brick are found in most of the deeper valleys of McKean County. Those having an outlet through the Allegheny River at the State line, namely, Tuna and Kinzua creeks, have more extensive clay beds than any of the others. They are usually surface deposits of rather limited extent.[a] Terrace clays are also worked for pottery manufacture at New Geneva and Point Marion, Fayette County; Greensboro, Greene County.

In Delaware County much clay is found at Morton station. Many deposits of loamy clay also occur in Upper and Lower Chichester townships.

Around Philadelphia the Columbia loams form an inexhaustible supply of clay for red brick and have been worked for a long period.[b]

Miscellaneous analyses of Pennsylvania clays.

	1.	2.
SiO_2	61.81	54.09
Al_2O_3	27.18	19.95
Fe_2O_3	6.96	9.84
CaO	2.00	.72
MgO	1.50	1.55
Na_2O		2.20
K_2O		3.31
Ign		8.98

1. Analysis of brick, Allegheny Brick Company, Limited, Allegheny.
2. Butler Brick and Tile Company, Butler, Pa.

CLAY-WORKING INDUSTRY.

Pennsylvania ranks second in the list of clay-producing States, Ohio being first, but in certain lines of ware, such as pressed brick, terra cotta, common brick, and fire brick, Pennsylvania outranks Ohio.

Though not the leading State, yet there are probably few others, if, indeed, any, in which the raw materials used by the clay worker are so uniformly distributed. This can be seen by consulting the maps showing the production of paving brick, fire brick, and pottery (Pls. VIII and IX).

Common brick.—This class of ware is manufactured all over the State, although local expansions of the industry are seen around the larger cities, as Philadelphia, Pittsburg, Allentown, Lancaster, Reading, Pottstown, and Scranton. The materials used are commonly surface or alluvial clays, but shales and residual clays are often

[a] Second Pennsylvania Geol. Survey, Rept. R, p. 87. [b] Idem, Rept. C5, p. 9.

found adaptable. In the Allegheny River Valley shales are worked at Harmarville, Sharpsburg, Millvale, Barking, Allegheny, etc.

Pressed brick.—The red Philadelphia pressed brick made from the Columbia loams around Philadelphia have won a high reputation in former years, but are not so much used now as those made from the fire clays in the western part of the State, for the color of the latter is better liked by most architects at the present time. These buff brick are now being turned out in large quantities.

Paving brick.—Pennsylvania again stands second to Ohio in the output of this grade of product, because, while the materials suitable for their manufacture are more widely distributed over the State, still, the great market of the central States being farther off, there is less inducement to build up a paving-brick industry in this State.

The industry in western Pennsylvania is not so extensive as the fire-brick or building-brick industry. Paving brick are manufactured at many points along with other classes of brick, as at Connellsville, Layton, Kittanning, Fallston, Blacklick, Harmarville, Rochester, Johnstown, Mount Braddock, Hyde Park, Barking, and Bolivar. Most of the companies making them at these points make fire brick their chief product.

The distribution of the plants can be seen by reference to the map (Pl. VIII).

Fire brick.—Pennsylvania produces very nearly half of the fire brick made in the United States. This great yield is due to the location of a great iron and steel industry within the State, which creates a great demand for the refractory wares made. In addition to this, many thousands are also called for in the lining of coke ovens in the bituminous-coal districts, and for the kilns used in the various branches of the clay-working industry, which is in active operation in western Pennsylvania. In the vicinity of Bolivar the upper Freeport clay is worked to supply the several fire-brick works in that region. In this district fire clay has been mined for more than fifty years. Other fire-brick works are located at Nineveh, Johnstown, and South Fork, in the Conemaugh Valley, and there are also a number of other plants in the Allegheny, Ohio, and Youghiogheny valleys.

In addition to the works in the western part of the State, there are others in the extreme eastern portion which draw on New Jersey for their raw materials. The residual white clays of the South Mountain region are also used.

Glass pots form an important refractory product, and there are several large operators located in the State. This type of ware is made of a mixture of German, Missouri, and Pennsylvania clays.

Pottery.—The established potteries are confined chiefly to the western and eastern ends of the State, and the product includes white earthenware, ordinary and chemical stoneware, and common red earthenware.

New Brighton is a most important center, for here are three large factories making stoneware, and there is a large white ware works at Beaver Falls, as well as a flower-pot works. The establishment of the pottery industry at this locality dates back to the year 1834, and the conditions have been such that the industry has expanded along several different lines since that time.[a] The lower grades of ware are made from native clays, but the higher ones are manufactured from materials brought largely from other States. Some white ware is made in Philadelphia, and there has been a chemical stoneware factory in operation at that locality for a number of years. Art tile are made at Beaver Falls, and plain and encaustic floor tile are pressed at Pittsburg, the red burning shales of that vicinity producing a tile of great purity of color and density of body. Terra cotta is made to some extent, the factories being located at Philadelphia and New Brighton. Drain tile are also made at several localities, and the Kittanning clays at New Brighton are well adapted for the manufacture of sewer pipe.

The following table gives the total value of clay products produced in Pennsylvania from 1895 to 1901, and also the output of the individual grades of ware in 1900 and 1901:

Value of clay products of Pennsylvania from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$8,807,161	2	13.48
1896	9,063,313	2	14.54
1897	7,874,695	2	12.63
1898	9,642,098	2	13.47
1899	14,103,245	2	14.72
1900	13,391,748	2	13.92
1901	15,321,742	2	13.90

[a] Clays of western Pennsylvania: Ann. Rept. Pennsylvania State College, 1897, p. 36.

Value of clay products of Pennsylvania in 1900 and 1901.

	1900.	1901.
Common brick	$4,484,590	$5,357,079
Front brick	596,559	844,087
Vitrified brick	481,670	670,081
Fancy brick	57,279	74,726
Fire brick	4,587,991	4,791,083
Stove linings	90,348	86,190
Drain tile	8,420	7,409
Sewer pipe	522,650	438,998
Terra cotta	180,100	314,900
Fireproofing	95,957	101,652
Tile, not drain	191,878	188,525
Red earthenware	88,682	431,433
Stoneware	255,457	
White granite ware	830,000	839,903
Miscellaneous	920,167	1,175,676
Total	13,391,748	15,321,742

RHODE ISLAND.

The glacial clays of Rhode Island, excluding Block Island, are of limited extent. They occur at a few points around Narragansett Bay, but the principal occurrence is in the town of Barrington. They underlie an area of about 1 by 1½ miles a few feet above tide level.[a] They are bluish gray, and sandy in their upper portion. Their depth reaches 60 to 65 feet. The production of Rhode Island is included with that of Connecticut. (See p. 79.)

SOUTH CAROLINA.

There has perhaps been less published regarding the clay resources of this State than those of any other east of the Mississippi except Delaware. The northwestern part of the State is underlain by crystalline rocks, which extend to the edge of the Coastal Plain, the line of division passing a short distance southeast of Chesterfield and Camden, through Columbia and west of Aiken.

RESIDUAL CLAYS.

These may be looked for throughout the crystalline belt, and are usually impure. No kaolins are reported, but many of the white-burning sedimentary clays found in the Coastal Plain are incorrectly termed such.

[a] Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, p. 987.

COASTAL PLAIN CLAYS.

The formations range from the Potomac to the Columbia, and consist of sands, clays, loams, and marls. Of the different formations the Potomac and Columbia are perhaps the most important to the clay worker, though the others might contain local clay deposits of value.

The Potomac outcrops in a belt from 4 to 5 miles wide, reaching from Augusta, Ga., through Aiken, south of Lexington, and through Columbia to Camden and Cheraw.[a] It contains lenses of white clay which are worked at Aiken, Columbia, Severn, and other points and sold to paper manufacturers. Some of these may be available for pottery or fire brick.

The Columbia loams are found on the lower lands and along rivers, and may be useful for brick manufacture.

Tuomey, in his report on the geology of South Carolina, published in 1848, states[b] that pottery clay is common in the Buhrstone formation (Eocene) and that a good clay occurs north of Hamburg and also near Graniteville and on Congaree Creek.

CLAY-WORKING INDUSTRY.

South Carolina ranks thirty-first among the clay-producing States, the production since 1895 having been as follows:

Value of clay products of South Carolina from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$276,918	30	0.42
1896	354,275	27	.57
1897	290,497	30	.48
1898	259,232	35	.33
1899	605,329	28	.63
1900	711,336	27	.73
1901	575,218	31	.52

[a] Bull. U. S. Geol. Survey No. 138, p. 208.
[b] Page 289.

Value of the clay products of South Carolina in 1900 and 1901.

	1900.	1901.
Common brick	$665,998	$546,028
Front brick	10,784	1,188
Fire brick	14,321	14,925
Stove linings	.....	(a)
Drain tile	.....	(a)
Miscellaneous	300	250
Pottery	17,633	11,872
Clay	79,900	143,700

a Less than three firms.

TENNESSEE.

The geologic formations occurring in Tennessee belong to the pre-Cambrian, Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Eocene, and Pleistocene. The pre-Cambrian rocks occur in small areas along the eastern border, while west of them and folded into many narrow belts lie rocks of Cambrian to Silurian age. The Carboniferous reaches from the eastern edge of the Cumberland Plateau westward beyond the Tennessee River. In the central part of the State is a large area of Silurian, and another along the Tennessee River in the southern half of the State. This is followed on the west by a broad belt of Tertiary, which in turn is separated from the Mississippi River by a strip of Pleistocene.

PRE-CAMBRIAN.

No kaolin deposits have been described from the crystalline area of northeast Tennessee, but they may exist, as they are abundant in western North Carolina.

PALEOZOIC RESIDUAL CLAYS.

The rocks of these formations yield residual clays from both limestones and shales, and the latter might also grind up to a plastic mass. In parts of Cumberland, Rhea, Loudon, Meigs, Roane, Grundy, Franklin, Marion, and Sequatchie counties the residual red or blue clays of the Chickamauga limestones are well adapted for making bricks. These clays and some from Cambrian shales are extensively used in adjacent areas for making drain tile. Others are found around Pikeville.[a] In the region around Knoxville[b] the calcareous Athens shale also yields a residual brick clay which accumulates in the hollows. These clays are worked at Maysville and Knoxville.[c] The Knox dolomite also yields a stiff clay, which may

a Geologic Atlas U. S., folio 21, Pikeville. b Idem, folio 16, Knoxville. c Idem, folio 59, Bristol.

at times contain much chert. The Conasauga and upper part of the Rome formation likewise yield residual clays.[a] Along the Tennessee-Georgia boundary the residual clays derived from the Bangor and Chickamauga limestones are suited for the manufacture of brick and tile. Some of the highly siliceous residual clays from the Knox dolomite are refractory,[b] and fire brick are made from them near Cleveland. The Bangor limestone weathers to red and blue residual clays which are worked at many localities in parts of Warren, Dekalb, Grundy, White, and Van Buren counties. Others are found in the region around Pikeville,[c] Standingstone,[d] Wartburg,[e] and Maynardsville.[f] Near Smithville a white clay derived from the slate in the upper part of the Fort Payne division, is used for pottery.[g]

CARBONIFEROUS.

J. M. Safford, in his report on the Geology of Tennessee, published in 1869, refers to the following occurrences of clay in the Carboniferous:

Near the Cumberland Iron Works, in Stewart County, is a bed of fire clay of Lower Carboniferous age;[h] another occurs 4 miles southwest of Cumberland City, in Stewart County; in the valley of Crow Creek, near Anderson station, the Coal Measures at the margin of the table-land show a fire clay 3 feet thick, 163 feet below the top of the cliff;[i] in Franklin County, near the Grundy County line, and 4 miles northwest of the track of Sewanee road, at the old Logan bank, is a bed of clay 115 feet below the conglomerate;[j] near the lower end of the Battle Creek Valley, in Marion County, is a bed of fire clay 2 feet thick; 5 miles southeast of Tracy City, and 1½ miles from Parmley Bank, a bed of clay underlies the main Sewanee coal;[k] another occurs at the north end of Lookout Mountain, below the Upper Conglomerate.[l] Many of the under clays of the coal seams, according to Safford, are of refractory character.[m] Fire clays, mostly undeveloped, are said to be associated with the coals in the areas covered by the following Geologic Atlas folios: Standingstone, No. 53; Wartburg, No. 40 (used for pottery).[n]

In the Kingston region the beds of clay which underlie the coals are no doubt refractory in many cases, but they are wholly undeveloped.[o]

TERTIARY.

In western Tennessee the plastic clay immediately underlying the Lafayette formation serves as the basis of a rather active stoneware and fire-brick industry.

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[a] Geologic Atlas U. S., folios 4 and 8, Kingston and Sewanee.
[b] Idem, folio 2, Ringgold.
[c] Idem, folio 21, Pikeville.
[d] Idem, folio 53, Standingstone.
[e] Idem, folio 40, Wartburg.
[f] Idem, folio 27, Morristown.
[g] Idem, folio 22, McMinnville.
[h] Safford, Geology of Tennessee, p. 349.
[i] Ibid., p. 372.
[j] Ibid., p. 373.
[k] Ibid., p. 380.
[l] Ibid., p. 385.
[m] Ibid., p. 513.
[n] Geologic Atlas U. S., folio 33, Briceville; folio 21, Pikeville; folio 4, Kingston.
[o] Idem, folio 4, Kingston.

The section usually seen in the clay pits involves red Lafayette sands, which seem to overlie unconformably the beds of stoneware clay and white sands.

One pottery, located at Grand Junction, used clay from the various pits of the vicinity. The clay varies in quality. In the pits of the Irwin Clay and Sand Company, 1¼ miles east of the station, along the railroad, the section given by E. C. Eckel[a] is—

Section near Grand Junction, Tenn.

	Feet.	Inches.
Red sand.		
White sand	8	
White clay	8	
Gray lignitic clay	8	10
White clay	20	
White sand.		

The clay deposits are very irregular, sometimes running together to form overlapping lenses in the white and yellow sand. The Lafayette seems to overlie the section. At Jackson there is another pottery for making stoneware, and the section here is somewhat similar. At Pinson is still another stoneware plant, which also makes fire brick and tiles. There are several around Pinson, all of which show the clay associated with the sands. Some of the clay from Pinson is sent to Jackson for use in the pottery there. The Pinson clay pits are all southwest of the station. Another pottery is at Mackenzie.[b]

The clay at Hico, 3 miles south of Mackenzie, is shipped to the potteries at Akron and East Liverpool, Ohio, and Louisville, Ky. The clays from Hollow Rock are shipped to Nashville. There is a large pottery at Toone and one being erected at Henry. Two potteries are also located near Paris.

Three miles east of Currier are the pits of I. Mandle, where an area 60 by 50 feet has been opened up. The section is as follows:

Section at Mandle's clay pits, 3 miles east of Currier, Tenn.

East side.	West side.
2 feet clay.	Reddish sand.
4 feet clay.	15 feet light-gray clay.
1 foot black clay (lignitic).	1 foot black clay.
5 feet brown clay (ball clay).	5 feet ball clay.

The bases of the two sections are at the same level, hence the type beds are very irregular. The light-gray clay is shipped to East Liverpool, Ohio, for saggers. The ball clay is known as Tennessee ball clay No. 3. Tests of samples of this clay supplied

[a] MS. notes. [b] From MSS. of E. C. Eckel.

by I. Mandle, made by S. Geijesbeek, show that it leaves 10 per cent residue on a 175-mesh sieve. Its rational composition is—

Analysis of clay from Mandle's clay pits, near Paris, Tenn.

	Per cent.
Clay substance	91.35
Feldspar	2.70
Quartz	5.95

It will carry as much as 72 per cent of nonplastic material. The shrinkage at cone 1 is 12.5 per cent; at cone 2, 18 per cent. It burns white at cone 1 and gray at cone 8, being vitrified at that temperature. This is located 5 miles from Paris, and the clay is shipped from Currier, which is 3 miles from the mine.

Tennessee ball clay, No. 1, found in Henry County, shows the following rational analysis:

Analysis of ball clay from Henry County.

	Per cent.
Clay substance	86.20
Feldspar	2.70
Quartz	11.10

It carries 60 per cent nonplastic material to the mixture. The total fire shrinkage at cone 8 is 15 per cent, and at this temperature it burns to a cream-white color and dense body.

ALLUVIAL CLAYS.

Alluvial clays are found in many of the river valleys, and in most cases are the wash from the residual clays of surrounding areas. They often underlie the river terraces. These terrace clays are used in the Maynardville area.[a] Others are common in the region around Morristown,[b] especially in the low grounds of the Lick Creek, Nolichucky, and French Broad valleys.

The following analyses of Tennessee clays have been gathered from different sources:

Analyses of Tennessee clays.

Locality.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Alk.	H_2O.	Moisture.	MnO.	Remarks.
Loudon	45.06	30.03	[a] 4.50	4.70	4.80	.....	10	1	.....	Crossley, analyses of clays.
Powdes Station	68.35	12.96	6.44	.23	1	2.14	7	8	0.9	J. W. Slocum, analyst.
Chattanooga	68.96	20.42	1.84	.16	.33	2.18	6.50	.....	Tr	Tennessee Paving Brick Co.
Robbins	70.57	15.19	7.97	.78	.32	2.80	.....	.....	.....	Clay Worker, December, 1893.

[a] See Geologic Atlas U. S., folio 75, Maynardville.
[b] Idem, folio 27, Morristown.

CLAY-WORKING INDUSTRY.

Tennessee ranks twenty-fifth among the clay-producing States, the production since 1895 having been as follows:

Value of clay products of Tennessee from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$522,534	23	0.80
1896	537,325	23	.86
1897	612,293	22	.98
1898	513,738	22	.72
1899	948,853	22	.99
1900	915,578	23	.95
1901	893,967	25	.81

Value of the clay products of Tennessee in 1900 and 1901.

	1900.	1901.
Common brick	$609,994	$610,968
Front brick	59,493	32,350
Vitrified brick	87,760	67,129
Fancy brick	(a)	(a)
Fire brick	32,573	37,100
Drain tile	18,900	15,961
Sewer pipe	(a)	(a)
Fireproofing	(a)	(a)
Stoneware	48,325	62,093
Fire clay	2,697	32,957
Stoneware clay	808	
Raw	3,750	
Total	915,578	893,967

a Production not given where less than three factories supplied.

VIRGINIA.

The crystalline rocks, consisting of granites, gneisses, and schists, with some intrusives, cross the State from north to south in a belt of increasing width, whose western boundary follows approximately a line running from Harpers Ferry south-

westward, passing a few miles east of Front Royal. The eastern edges pass through Alexandria, Fredericksburg, Bothwell, Richmond, and Petersburg.

The Cambro-Silurian rocks form a broad belt lying west of the crystalline belt and extending to the Virginia-West Virginia boundary with the exception of an area of Carboniferous in the extreme southwestern portion.

The Newark group occupies several narrow belts within the crystalline region.

Southeast of the crystalline belt and underlying the Coastal Plain area is a series of mostly unconsolidated sands and clays. The Coastal Plain area lies east of a line running through Alexandria, Fredericksburg, Bothwell, Richmond, Petersburg, and Emporia, and covers 9,800 square miles. The geologic structure is similar to that of eastern Maryland, but the Potomac beds are more sandy. Darton[a] gives following Coastal Plain formations:

Coastal Plain formations of Virginia.

Formation.	Character of beds.	Age.
Columbia	Loams, sands, and gravels in terraces	Pleistocene.
Lafayette	Orange sands, loams, and gravels	Pliocene.
Chesapeake	Clays, sands, infuserial earth, and marl	Miocene.
Pamunkey	Clays, marls, and sands	Eocene.
Potomac	Sands, sandstone, and clays	Early Cretaceous.

CRYSTALLINE AREA.

The decomposition of the rocks throughout this area may give rise to residual clays, usually of impure character, which are thicker on the gentler slopes or level surfaces, but the wash from them is often found in the valleys. They are usually adapted to the manufacture of common brick. Prof. J. B. Woodworth informs me that at Clayville, Powhatan County, the gneisses weather to a residual clay, which is used in the manufacture of light-colored brick. The granite along the eastern border of the crystalline belt forms a yellow clay often as much as 20 feet deep.

Kaolin.—This is found in Henry and Patrick counties, and perhaps elsewhere, but the deposits are just being developed. It is also said to occur in Ashe County, on the South Fork of New River, and near Wytheville, Wythe County, as well as in Smyth County.[b] Kaolin and fire-clay mines are said to have been opened in Nelson County, near the line of the Southern Railway,[c] but nothing has been published regarding them in recent years. The occurrence of kaolin has also been noted from a locality known as Bon Air, 9 miles from Richmond,[d] and from the crystalline area of Prince Edward and Cumberland counties, a little east of their court-houses.[e]

[a] Bull. U. S. Geol. Survey No. 138, p. 162.
[b] Mineral Resources U. S. 1882, p. 470.
[c] The Virginias, Vol. III, p. 160.
[d] Ibid.
[e] Rogers, Geology of the Virginias, p. 284.

CAMBRO-SILURIAN CLAYS.

The Cambro-Silurian shales and limestones yield an abundance of impure residual clay, which is well adapted to brick manufacture. These clays are likely to be found throughout the region of the Great Valley.

Some of the residual clay found near the zinc deposits in Pulaski County may contain zinc. It has no special commercial value on this account, however.[a] Its composition was:

Analysis of residual clays in Pulaski County, Va.

SiO_2	37.38
Al_2O_3	24.67
Fe_2O_3	6.34
MnO	12.10
MgO	.27
K_2O	.47
Na_2O	.27
Ign	10.35
Moist	6.69

White residual clay is also reported from Black Rock.[b]

CARBONIFEROUS.

Though containing important beds of coal, the clayey members of the formation have received but little notice.[c]

W. B. Rogers[d] states that on Ryders Creek, in the region west of the Greenbrier River and in the Kanawha Valley, yellow shales are found lying below a heavy seam of coal. They contain occasional lumps of kidney ore, but the shale was thought to be refractory.

At Catawba Furnace, Botetourt County, beds of fire clay are said to occur with the coal.[e] The beds dip from 30° to 50° away from Catawba Mountain.

TRIASSIC.

No mention is anywhere made of the use of the shales of this formation, but the mellowed outcrops of the more shaly members would no doubt prove serviceable. In the vicinity of Harpers Ferry they yield residual clays suitable for brick manufacture. They also form residual clays along their line of outcrops in the Richmond coal basin.

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[a] Heyward, B. H., On a zinc-bearing clay from the neighborhood of the Bertha zinc mine, Pulaski County, Va.: The Virginias, Vol. III, p. 4.

[b] The Virginias, Vol. IV, p. 58.

[c] For sections see M. R. Campbell, Geology of Big Stone Gap coal field: Bull. U. S. Geol. Survey No. 111, 1893.

[d] Geology of the Virginias, p. 376.

[e] The Virginias, Vol. IV, p. 161.

COASTAL PLAIN FORMATIONS.

These contain the most important clay deposits found in the State, but in all publications regarding them their economic value is rarely referred to.

The Potomac group is the basal member of the Cretaceous, and is exposed where the overlying ones have been eroded. These areas are narrow belts in the Nottoway, Appomattox, James, Pamunkey, and Rappahannock depressions, near the western Coastal Plain borders, and from a wide belt from Fredericksburg to Washington. The formation consists of sand, with beds of clay of variable size and shape. The lower beds of the formation dip gently eastward and lie usually on the crystalline rocks, but around Bothwell they rest on the Newark sandstones and shales. Pottery clays are said to be abundant in the Potomac beds around Fredericksburg and also below it.[a]

The Pamunkey formation is exposed north of the James River, but does not contain many clays of importance. The clays are referred to by W. B. Rogers,[b] who states that they usually contain many shell remains. Outcrops are seen at Herring Creek.

The Chesapeake formation can be well seen at many points, since it is cut into by the Rappahannock, Mattaponi, Pamunkey, and James rivers.[c] It consists chiefly of beds of clay, fuller's earth, shell marl, and fine sand. These clays may attain a great thickness. The Miocene clays may often contain sulphate of iron.[d] Many of them, however, are suited for pottery and brick manufacture.[e] Sandy Miocene clays occur in many parts of Hanover, King William, Henrico, and other counties. They are of greenish-gray or brown color and have an astringent taste.[f]

The Lafayette formation.—This, lying on the surface of ridges between the valleys, is probably of little importance to the clay worker, but occasionally contains beds of brick clay.

The Columbia formation, which caps terraces along the Potomac, Rappahannock, Mattaponi, Pamunkey, York, Chickahominy, James, and Blackwater rivers, and Chesapeake Bay, and which covers all of Norfolk and Princess Anne counties, may often carry brick loams,[g] so that these Columbia loams and other alluvial clays are found in many parts of the State. They are found in the stream bottoms of the Monterey region,[h] around Fredericksburg,[i] around Petersburg, and farther down the South Branch[j] in the Nomini region.[k]

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[a] Geologic Atlas U. S., folio 13.
[b] Geology of the Virginias, p. 435.
[c] Bull. U. S. Geol. Survey No. 138, p. 163.
[d] Geology of the Virginias, p. 45.
[e] Ibid., p. 49.
[f] Ibid., p. 50.
[g] Bull. U. S. Geol. Survey No. 138, p. 164.
[h] Geologic Atlas U. S., folio 61, Monterey.
[i] Idem, folio 32, Franklin.
[j] Idem, folio 13, Fredericksburg.
[k] Idem, folio 23, Nomini.

OTHER UNCLASSIFIED OCCURRENCES.

Great beds of blue sandy clay are reported in the section of the Stratford and Chantilly cliffs in Westmoreland County, along the Potomac.[a] Material termed kaolin is reported from near Sherando, 7 miles southwest of Waynesboro, in the alluvial lands between Back Creek and South Fork of the Shenandoah. The clay, which is said to be 30 feet thick in places,[b] is involved in the following section:

Section near Sherando, Va.

Surface of sand, gravel, and cobbles.
Yellowish clay.
White clay.

Analysis of clay from near Sherando, Va.

Its analysis gave:

SiO_2	47.90
Al_2O_3	39.86
Fe_2O_3	.24
CaO	.23
MgO	.19
Alkalies	1.55
H_2O	9.85
Total	99.72

CLAY-WORKING INDUSTRY.

Virginia ranks very low as a producer of clay products. The total production since 1895 has been as follows:

Value of clay products of Virginia from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$855,768	18	1.31
1896	879,526	17	1.41
1897	812,046	16	1.30
1898	889,883	17	1.24
1899	1,093,784	19	1.14
1900	1,305,195	15	1.36
1901	1,439,347	19	1.31

[a] Geology of the Virginias, p. 428.

[b] The Virginias, Vol. IV, p. 47.

The value of clay products in 1900 and 1901 was as follows:

Value of clay products of Virginia in 1900 and 1901.

	1900.	1901.
Common brick	$934,185	$1,139,894
Front brick	275,847	267,028
Vitrified brick	44,067	.....
Fancy brick	17,921	20,429
Fire brick	26,573	3,971
Drain tile	3,285	3,978
Sewer pipe	(a)	.....
Earthenware	425	(a)
Miscellaneous	2,392	4,047

a Included in miscellaneous.

WEST VIRGINIA.

The western three-fourths of this State is underlain by rocks of Carboniferous age, while the eastern fourth is covered by Cambro-Silurian rocks, crossing the State in more or less parallel bands, due to their folded structure.

Since there are no pre-Cambrian crystalline rocks found in the State, kaolins of the North Carolina type are not to be looked for, but some white clay may occur in the residual products of the Cambrian and Silurian formations of the eastern part of the State.

CARBONIFEROUS.

The Carboniferous section of West Virginia is very similar to that of Pennsylvania. The general distribution and character of the clays can best be seen by consulting the map (Pl. III).

POTTSVILLE CONGLOMERATE.

This formation in West Virginia shows many massive sandstone beds, but according to the sections given by I. C. White[a] fire clay is seen in the sections at several localities. Thus at Piedmont, Mineral County, dark sandy fire clay 12 feet thick is noted under the second coal below the Homewood sandstone and 5 feet thick under the fourth coal. Again, at the mouth of the North Fork of Blackwater, Tucker County,[b] a bed of fire clay is found between the second and third coals under the Homewood sandstone. Here it is 2 feet thick. The same section also shows numerous shale beds.

a Bull. U. S. Geol. Survey No. 65, p. 138. b Ibid., p 187.

Still another section, taken near the mouth of Sandy Creek, or on Cheat River, Preston County, shows a 7-foot bed of fire clay underlying the coal.

The Mount Savage fire clay of Maryland and Pennsylvania seems to be missing in the West Virginia section.

LOWER COAL MEASURES.

The surface areas of these are again so scattered that the map in Bulletin 65, United States Geological Survey, should be consulted.

These measures may be in place carrying beds of fire clay under the Freeport and Kittanning coals, as in Pennsylvania, but the beds are not as extensive or persistent. The following sections indicate their character:

Section at Newburg, Preston County, W. Va.

		Ft.	In.
1. Coal, Upper Freeport	Coal ..... 3 feet Coal and slate, 2 feet 4 inches	5	4
2. Shales	8 feet		
3. Sandstone	18 feet		
4. Limestone, Upper Freeport	8 feet		
5. Shales	6 feet	45	0
6. Iron ore	1 foot		
7. Shales	4 feet		
8. Fire clay (horizon of Lower Freeport coal)		2	0
9. Shales, gray	14 feet		
10. Shale, dark	11 feet		
11. Shale, gray	9 feet	108	0
12. Sandstone, Freeport	74 feet		
13. Coal, Upper and Middle Kittanning	Coal ..... 1 foot Slate ..... 3 inches Coal, slaty ... 2 feet Fire clay ..... 2 feet Coal, good ... 2 feet	7	3
14. Fire clay and shales with iron ore nodules		15	0
15. Coal, Lower Kittanning	Coal ..... 10 inches Shale, gray ..... 10 inches Coal ..... 6 inches Coal, bony ..... 3 inches Coal, main bench ... 4 feet 6 inches Black slate ..... 6 inches Coal ..... 2 feet	9	5
16. Sandstone and shale		38	0
17. Pebbly sandstone, top of No. XII.			
Total		230	0

Section at Piedmont, Mineral County, W. Va.

		Ft.	In.
1. Coal, Upper Freeport	Coal 2 feet; Shale and bone 1 foot; Coal 2 feet	5	0
2. Concealed	10 feet	20	0
3. Shale, bluish	10 feet		
4. Coal, Lower Freeport		2	0
5. Fire clay	2 feet	74	0
6. Concealed	10 feet		
7. Sandstone, hard	2 feet		
8. Sandstone, shaly	5 feet		
9. Shales, sandstone, and concealed	55 feet		
10. Coal, Upper Kittanning	Bituminous slate 5 feet; Coal 2 feet	7	0
11. Dark shales, and concealed	10 feet	65	0
12. Massive sandstone, gray	50 feet		
13. Shales, drab	5 feet		
14. Coal, Lower Kittanning	Coal, slaty 1 foot; Coal, bony 8 inches; Coal, good 1 foot 4 inches; Slate, hard ½ inch; Coal, good 2 feet 6 inches	5	6½
15. Fire clay, sandy	3 feet	89	0
16. Shales, with nodular iron ore	2 feet		
17. Fire clay, impure	4 feet		
18. Flaggy sandstone	20 feet		
19. Concealed	25 feet		
20. Fire clay, sandy	10 feet		
21. Flaggy sandstone and sandy shales	25 feet		
22. Concealed, and sandy shales		40	0
23. Top of No. XII			
Total		307	6½

Section near Thomas, Tucker County, W. Va.

		Ft.	In.
1. Coal, Upper Freeport	Coal 3 feet; Bone and bony coal 2 feet; Coal 3 feet	8	0
2. Sandy, shales, weathering reddish		40	0
3. Coal, Lower Freeport	Coal 2 inches; Shale 4 inches; Coal 1 foot	1	6
4. Concealed	10 feet	70	0
5. Massive pebbly sandstone, Freeport	60 feet		
6. Coal, streak, Upper Kittanning			

Section near Thomas, Tucker County, W. Va—Continued.

		Ft.	In.
7. Fire clay and shales		35	0
8. Coal, Middle and Lower Kittanning	Coal, good 1 foot 5 inches Slate 4 inches Coal, good 1 foot Slate 3 inches Coal, good 3 feet 6 inches Shale, gray 1 foot 6 inches Coal, slaty 3 feet	11	
9. Concealed	5 feet		
10. Massive sandstone	20 feet		
11. Shales	2 feet		
12. Iron ore, burrstones	1 foot	65	0
13. Limestone, ferriferous	2 feet		
14. Shales and sandstone	35 feet		
15. Coal, Clarion		3	0
16. Shales		40	0
17. Sandstone, top of No. XII.			
Total		273	6

In the sections on the North Potomac, at the Maple Swamp water tank on the West Virginia Central Railroad, the clays, if present, are concealed.

Fire clay is noted under the Lower Kittanning coal at Valley Falls, Taylor County, where it is 5 feet thick. It may occur under the Upper Freeport, but in the section was concealed.

Near Nuzums Mills the following section is obtained:

Section at Nuzums Mills (now Hammond), Marion County, W. Va.

		Ft.	In.
1. Coal, Upper Freeport		3	0
2. Clay	2 feet		
3. Sandstone	15 feet		
4. Limestone, Upper Freeport	3 feet		
5. Shales and concealed	13 feet	58	0
6. Sandstone, coarse	10 feet		
7. Shales, sandy, drab	15 feet		
8. Coal, Lower Freeport		5	7
9. Shales and concealed	30 feet	55	0
10. Massive sandstone, Freeport	25 feet		
11. Coal, Upper Kittanning		2	0
12. Shales, dark, sandy, with limy beds	40 feet	43	0
13. Black slate	3 feet		
14. Coal, slaty, Middle Kittanning		1	0

Section at Nuzums Mills (now Hammond), Marion County, W. Va.—Continued.

		Ft.	In.
15.	Shales and sandy beds	20	0
16.	Coal, Lower Kittanning	5	0
17.	Fire clay — 5 feet		
18.	Sandstone, flaggy — 5 feet		
19.	Dark shales, with iron-ore nodules — 12 feet		
20.	Iron ore, Ferriferous limestone horizon — 6 inches	30	0
21.	Dark shales — 5 feet		
22.	Black slate — 2 feet 6 inches		
23.	Coal, Clarion	0	1
24.	Fire clay, sandy — 3 feet		
25.	Dark shales, with iron-ore nuggets near middle — 20 feet	33	0
26.	Flaggy sandstone — 10 feet		
27.	Concealed and coal blossom, Brookville	6	0
28.	No. XII conglomerate.		
	Total	261	8

The Hammond Fire Brick Company, at Hammond, is working 12 feet of Lower Kittaning clay at present (May, 1902), of which the upper half is flint clay and the lower half plastic clay. The composition of the flint clay supplied by the company is given below.

Analysis of flint clay, Hammond, Marion County, W. Va.

SiO_2	48.78
Al_2O_3	32.71
Fe_2O_3	1.14
TiO_2	2.70
CaO	.23
MgO	.04
K_2O	.56
H_2O	13.84
Total	100

Between cuts Nos. 80 and 81, west of Rowlesburg, on the Baltimore and Ohio Railroad, the section, according to I. C. White,[a] shows 10 feet of impure fire clay about 28 feet under the Upper Freeport limestone. Forty feet below the Upper Kittanning coal is a 10-foot bed of shales, and 75 feet below the Middle Kittanning or Darlington seam there is a 10-foot fire-clay bed with iron-ore nodules.

Opposite Coalburg, on the Chesapeake and Ohio Railroad, the section shows 5 feet of fire clay below the Cedar Grove coal of the Lower Productive Measures.[b]

The following analyses of Lower Kittanning clay from Spragueville, W. Va., are given by I. C. White:[c]

[a] Notes on the geology of West Virginia: The Virginias, Vol. II, p. 102.
[b] Ibid., p. 137.
[c] Private report on Spragueville mineral property.

Analyses of clay from Lower Kittanning beds at Sprague ville, W. Va.

	1.	2.
Silica	47.880	68.315
Alumina	33.985	19.620
Oxide of iron	1.368	1.575
Titanic acid	3.185	1.370
Magnesia	.346	.692
Lime	.360	.100
Potash	.079	2.345
Soda	.402	.359
Water	12.388	5.580
Total	99.993	99.956

1. "Hard" clay from Spragueville, W. Va., McCreath.
2. "Soft" clay from Spragueville, W. Va., McCreath.

Below are given some additional fire-clay analyses taken from various sources.

Analyses of West Virginia fire clays.

	1.	2.	3.	4.	5.
SiO_2	53.100	59.008	45.86	68.16	54.27
Al_2O_3	32.406	23.061	44.23	24.11	33.83
Fe_2O_3	1.256	4.350	.....	.01	.01
CaO	.210	.892	.24	Trace.	Trace.
MgO	.421	.976	.36	Trace.	.02
Alk	.397	2.561	Trace.	Trace.	Trace.
H_2O	12.27	9.152	8.35	6.66	10.86
Moisture	.....	.....	.70	.85	1.00
Total	100.00	100.00	99.74	99.79	99.99

1. Flint clay. Supplied by West Virginia Fire Clay Company, Thornton, W. Va.
2. Plastic clay. Supplied by West Virginia Fire Clay Company, Thornton, W. Va.
3. Marion County. From Report on the Natural Resources of West Virginia, prepared for World's Columbian Exposition by G. W. Summers, 1893.
4. Preston County. From Report on the Natural Resources of West Virginia, prepared for World's Columbian Exposition by G. W. Summers, 1893.
5. Monongalia County. From Report on the Natural Resources of West Virginia, prepared for World's Columbian Exposition by G. W. Summers, 1893.

The Bolivar fire clay, which underlies the Upper Freeport coal and replaces the Upper Freeport limestone, is of value in only one region in West Virginia, viz, on Deckers Creek, in Preston and Monongalia counties.[a]

[a] Bull. U. S. Geol. Survey No. 65, p. 160.

The Lower Kittanning clay is said to be rarely of value in West Virginia,[a] except along the Upper Ohio River, as it is usually too sandy. It has been developed at Hammond, on the Tygart River, where it takes the place of the coal.

The Lower Coal Measures fire clays are also worked in the vicinity of New Cumberland, Hancock County, for making paving brick and other clay products.

BARREN MEASURES.

These attain considerable thickness in West Virginia, being 800 feet near Charleston and about 600 feet near the Pennsylvania border. Important beds of shale occur at many localities, as can be seen by reference to the accompanying section, fig. 10.

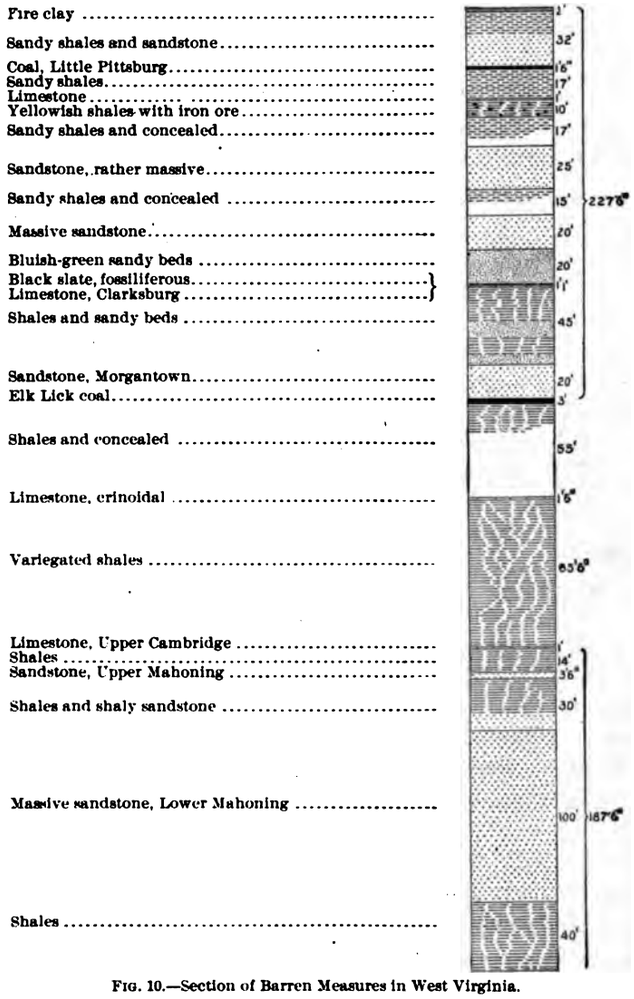

FIG. 10.—Section of Barren Measures in West Virginia.

[a] Bull. U. S. Geol. Survey No. 65, p. 172.

The Barren Measure shales are worked at Morgantown, just above the Mahoning sandstone. At Huntington, Cabell County, a red shale from the same measures is worked up into roofing tile. These are also worked at Clarksburg, Fairmont, and Charleston.

Good sections are given by I. C. White at Little Falls, Monongalia County,[a] Newburg, Preston County,[b] and Fairfax Knob, Tucker County.

The section at Huntington, according to I. C. White,[c] is as follows:

Section at Huntington, W. Va., along Ohio River.

	Feet.	
1. Pittsburg coal.		
2. Red shale, containing limestone nodules	28	
3. Sandstone, shaly	16	
4. Red shales and shaly sandstone	101	
5. Coal, Little Clarksburg	2	
6. Sandstone, massive, Morgantown	50	
		197
7. Elk Lick coal		2
8. Fire clay	3	
9. Shales, deep red	103	
		106
10. Limestone, crinoidal		2
11. Coal, crinoidal	2	
12. Red shales	4	
13. Limestone	4	
14. Shales and sandstones	175	
		185
15. Limestone, Lower Cambridge		2
16. Shales	10	
17. Coal, Masontown	1	
18. Shales	30	
19. Sandstone, Mahoning	125	
		166
20. Upper Freeport coal.		
Total		660

UPPER COAL MEASURES.

These, though of diminished thickness in West Virginia, carry, nevertheless, a great thickness of shale beds, those found immediately over the Pittsburg coal being often well adapted to the manufacture of vitrified brick. Good sections are exposed at Robinsons Run, Monongalia County (fig. 11), and on Scotts Run, same county; on Buffalo Creek, Marion County, where a 4-foot bed of fire clay is represented as occurring under the Uniontown coal. At Moundsville, Marshall County, a 7-foot

[a] Bull. U. S. Geol. Survey No. 65, p. 80. [b] Ibid., p. 81. [c] Ibid., p. 84.

bed of fire clay is said to underlie the Redstone coal. Many red shales also outcrop in the bluffs above Hartford, Mason County, and opposite Winfield, Putnam County.

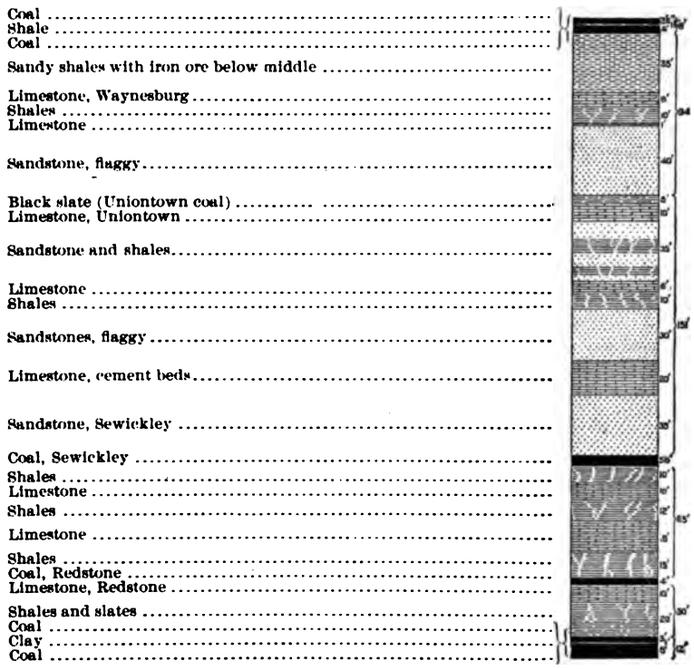

FIG. 11.—Section of Upper Productive Measures on Robinson Run, Monongalia County, W. Va.

In the Buckhannon area[a] fire clay occurs beneath many of the coal beds. Clay shales are found in both the upper and lower Coal Measures, but are not developed.

UPPER BARREN MEASURES.

According to I. C. White,[b] the beds of these cover a large area bordering the Ohio River between the Pennsylvania line at the north and the Kanawha River on the south. In West Virginia they carry great beds of red shale, which increase southward, while the limestone beds, so prominent farther north, decrease. These shales will no doubt in time become of great value to the clay worker as the industry of that region develops.

PLEISTOCENE CLAYS.

Two types of surface clays are found in West Virginia, viz, alluvial clays and residual clays.

The alluvial clays are found in the broader or older river valleys and are not infrequently the wash from neighboring hill slopes. Much of this material is found in the ancient channel of the Kanawha River and also in its present valley west of

[a] Geologic Atlas U. S., folio 34, Buckhannon.

[b] Bull. U. S. Geol. Survey No. 65, p. 21.

Charleston.[a] In the vicinity of Piedmont, clays are said to occur in the wider stream valleys, especially along the South Branch. In the old Kanawha River valley, known as Teays Valley, there is an abundant deposit of fine laminated clay, sometimes 50 feet thick.[b]

The residual clays are to be looked for in many of the valleys, or on gentle slopes, especially in areas that are underlain by shales or limestones. Clays of this type are common in the Great Valley.

CLAY-WORKING INDUSTRY.

The clay products produced in West Virginia from 1895 to 1901 had the following value:

Total values of clay products of West Virginia from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$895,777	17	1.37
1896	902,944	16	1.45
1897	1,115,254	13	1.79
1898	1,027,575	13	1.44
1899	1,451,539	13	1.52
1900	2,016,765	9	2.10
1901	1,946,480	9	1.77

Value of clay products of West Virginia in 1900 and 1901.

Product.	Value.	
	1900.	1901.
Common brick	$708,861	$348,452
Front brick	16,797	(c)
Vitrified brick	474,880	555,389
Fancy brick	.....	(c)
Fire brick	149,257	102,300
Draintile	1,346	1,485
Sewer pipe	(c)	(c)
Tile, not drain	(c)	(c)
Miscellaneous	655,797	505,912
Total plain pottery	222,949	297,842
Total decorated pottery	408,892	560,800
Raw clays	76,628	257,343

[a] Geologic Atlas U. S., folio 72, Charleston. [b] Idem, folio 69, Huntington. (c) Included in miscellaneous.

WISCONSIN.

The clay deposits of Wisconsin belong to two types, viz, residual and transported. The latter are much the more extensive, as they are closely associated in their origin to the glacial deposits of the State while the former occur only in the driftless area or in places where they have been protected by erosion.[a]

RESIDUAL CLAYS.

These have been derived from granite and gneisses, greenstones and allied volcanic rocks, limestone and dolomite, sandstone, and shale. Although these may have been abundant in former geologic times, most of the residual deposits were scraped off or carried away by the ice sheet during the Glacial epoch, and those now remaining are found only in the driftless area or in protected situations. The latter type occurs along the contact of pre-Cambrian schists with Potsdam sandstones, where the residual clays have been protected by the sandstone capping. In such cases the clay may extend to a depth of from 10 to 40 feet. Deposits of this nature occur in the vicinity of Grand Rapids, Eau Claire, Black River Falls, Rice Lake, and Stevens Point.[b] Though iron stained in their crude condition, it is claimed that they can be washed white. At the present time the shale residuals are used for the manufacture of soft mud, stiff mud, and dry press brick. The shales burn to buff or red color.

PLASTIC KAOLINS.

These are not true kaolins, but white burning sedimentary clays, which have been derived from the residual products of kaolinic schists and sorted by water action. The layers of clay and sand are interstratified, so that it has to be washed for market. One of these deposits occurs at Hersey, St. Croix County,[c] and has been worked since 1893. Other deposits occur in the valley of the Eau Claire River. Large quantities of this clay are washed annually and sold to the paper manufacturers of Minnesota and Wisconsin.

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[a] See Bull. Wisconsin Geol. and Nat. Hist. Survey No. 7: Clays and clay industries of Wisconsin, by E. R. Buckley from which the information relating to that State is abstracted.

[b] Ibid., p. 232.

[c] Ibid., p. 234.

The composition of these clays is given below:

Analyses of kaolinic schists or shales of pre-Cambrian rocks.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	70.30	59.88	50.17	72.30	55.87	65.52	67.96	61.22	75.66	49.86
Al_2O_3	18.07	18.10	17.90	16.06	19.60	16.33	17.25	13.98	12.19	27.41
Fe_2O_3	1.65	10.04	12.29	0.35	9.22	4.02	2.27	4.66	2.57	4.43
CaO	None.	0.31	0.55	0.26	1.05	1.65	0.67	3.76	0.82	0.48
MgO	6.90	3.13	6.86	1.50	3.71	3.09	2.07	2.03	0.72	2.10
Na_2O	0.76	0.52	0.58	0.40	0.32	0.33	0.38	1.32	1.53	0.52
K_2O	2.94	3.72	3.06	5.23	3.93	3.94	5.81	3.44	3.00	5.30
TiO_2	None.	.....	0.75	None.	.....	None.	None.	0.43	None.	None.
MnO	.....	Trace.	0.61	.....	.....	.....	.....	.....	None.	0.32
P_2O_5	0.06	.....	.....	Trace.	0.06	0.58	Trace.	.....	.....	.....
H_2O,C	5.26	4.40	7.16	3.68	6.22	4.38	3.86	9.10	3.79	9.41
Total.	99.94	100.10	99.93	99.78	99.98	99.84	100.28	99.94	100.34	99.83

	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
SiO_2	57.33	51.53	47.00	52.52	34.44	67.50	34.29	52.60	54.47	49.29
Al_2O_3	21.64	20.51	35.26	14.65	17.26	19.23	13.53	14.42	13.68	13.03
Fe_2O_3	5.57	8.10	3.03	18.07	23.80	2.60	16.73	16.00	15.96	20.20
CaO	0.85	0.90	None.	0.94	0.27	.....	0.47	0.65	0.55	0.31
MgO	2.67	4.02	0.28	2.40	11.21	0.83	5.66	3.15	3.17	4.15
Na_2O	0.64	0.66	0.31	0.34	0.22	0.48	0.15	0.36	0.40	0.40
K_2O	6.06	6.86	0.64	5.52	1.94	2.50	1.32	4.90	4.60	5.72
TiO_2	None.	0.25	0.25	1.35	0.47	.....	1.12	0.80	1.10	0.85
MnO	0.21	Trace.	.....	Trace.	1.55	SO_3 0.26	1.97	0.47	0.33	0.21
H_2O,C	5.21	7.22	3.14	4.69	9.10	6.47	C.13.87 H_2O 10.53	6.86	6.00	6.14
Total.	100.18	100.00	99.91	100.48	100.26	100.27	99.63	100.23	100.26	100.30

1. Halcyon Pressed Brick Company, Black River Falls, Jackson County. Wisconsin Geol. Nat. Hist. Survey, Bull. No. 7, p. 222.

2, 3. Halls Creek, Black River Falls, Jackson County. Ibid.

4–8. Halcyon Pressed Brick Company, Black River Falls, Jackson County. Ibid.

9–13. George T. Thompson (undeveloped), Eau Claire, Eau Claire County. Ibid., p. 270

14–16. Scott & Alexander, Grand Rapids, Wood County. Ibid., p. 271.

17. Graphite Works, Junction City, Portage County. Ibid., p. 272.

18–20. Clay Lumber Company, Ringle, Marathon County. Ibid., p. 273

Analyses of "kaolin."

	1.	2.	3.	4.	5.	6.	7.
SiO_2	61.89	73.14	65.19	58.95	64.50	52.41	58.19
Al_2O_3	18.84	11.64	25.34	29.56	26.20	34.10	18.77
Fe_2O_3	6.06	5.00	0.21	0.43	0.07	0.15	7.90
CaO	0.45	0.97	.....	.....	.....	0.05	0.59
MgO	1.29	0.88	.....	0.12	.....	0.12	3.92
Na_2O	1.22	1.30	.....	0.32	.....	0.18	0.10
K_2O	2.12	2.38	0.49	0.31	0.31	0.46	3.78
TiO_2	0.63	0.45	.....	.....	.....	0.80	0.55
MnO	0.17	0.18	.....	Trace.	.....	.....	Strong trace.
H_2O, C	7.43	4.58	8.80	10.23	8.90	11.89	6.18
Total	100.10	100.52	100.03	99.98	99.98	100.16	99.98

1. Undeveloped bed, Baldwin, St. Croix County. Wisconsin Geol. Nat. Hist. Survey, Bull. No. 7, p. 270.
2. Syme, Baldwin & Co., Glenwood, St. Croix County. Ibid., p. 271.
3. Undeveloped, Glenwood, St. Croix County. Ibid.
4. Undeveloped, Hersey, St. Croix County. Ibid., p. 272.
5. Superior China Clay Company, Hersey, St. Croix County. Ibid., p. 271.
6. Superior China Clay Company, Hersey, St. Croix County. Ibid., p. 272.
7. Undeveloped, Superior, Douglas County. Ibid., p. 274.

CLAYS OF DRIFTLESS AREA.

These lie in an area in the southeastern portion of the State which has not been modified by glacial action. The clay deposits are chiefly residual, formed by the decomposition of the underlying rock. Such are usually found in the slopes and ridges, while the valleys contain clay beds representing the wash from the residuals. These transported clays are the richest found in the driftless area. They are used at a number of points for the manufacture of common brick, but are not used in large quantities.

POTSDAM SHALES.

Alternating layers of tough plastic clay and sandstone occur at the base of the Potsdam in places, but in others the two are so mingled as to form a brown shale, which runs from 7 to 10 feet in thickness. This shale or clay is found at a number of points, notably Merrillan, Durand, Black River Falls, Eau Claire, Neillsville, and Fond du Lac. At the present time they are not used for the manufacture of clay products. The chemical composition can be seen from the following analyses:

Analyses of shales of Potsdam formation.

	1.	2.
SiO_2	62.59	62.97
Al_2O_3	17.42	18.42
Fe_2O_3	5.88	3.36
CaO	None.	None.
MgO	1.24	1.03
Na_2O	0.52	0.56
K_2O	8.08	8.68
TiO_2	0.30	0.35
SO_3	Trace.	Trace.
H_2O,C	4.15	4.97
Total	100.18	100.34

1. Undeveloped, Merrillan, Jackson County. Wisconsin Geol. Nat. Hist. Survey, Bull. No. 7, p. 273.

2. Undeveloped, Merrillan, Jackson County. Ibid.

HUDSON SHALE.

The Hudson shale forms a narrow belt in the eastern part of Wisconsin, and lies between the Trenton and Niagara limestone formations. It is a very calcareous shale, with occasional interlaminations of limestone, and the outcrops extend from the southern boundary of Wisconsin to Green Bay. Where exposed to the weather the shale breaks down fast to a powdery mass. On account of its calcareous character (as seen by the analyses below) the clay is not suited to the manufacture of paving brick, but does give very satisfactory results in common brickmaking.

In using this shale, however, it is always necessary to weather it for a season and grind it in dry pans before tempering. An advantage urged for this shale over the calcareous brick clays is that the latter contains lime in pebbles, while the former carries the calcium carbonate in a finely divided condition. Although worked at only two localities, it is molded in stiff mud, soft mud, and dry-press machines.

Analyses of Hudson shales.

	1.	2.
SiO_2	35.93	31.70
Al_2O_3	11.75	9.19
Fe_2O_3	4.08	3.76
CaO	12.43	15.37
MgO	9.92	10.90
Na_2O	1.24	0.68
K_2O	2.46	2.74
TiO_2	0.30	0.25
MnO	0.10	0.27
H_2O,C	22.06	25.17
Total	100.27	100.03

1. Frenzel Bros., Oakfield, Fond du Lac County. Wisconsin Geol. Nat. Hist. Survey, Bull. No. 7, p. 273.

2. Frenzel Bros., Oakfield, Fond du Lac County. Ibid.

PLEISTOCENE CLAYS.

The Pleistocene clays of Wisconsin can be grouped as follows: (1) Lacustrine deposits; (2) stream deposits; (3) estuarine deposits; and (4) glacial clays.

LACUSTRINE DEPOSITS.

These represent a very extensive type of deposit, and were laid down during the former inland extension of the Great Lakes, so that they are now often found at some distance from the present lake shore. Thus around Racine they occur 18 miles inland. They are also found at Sheboygan, over all parts of Door County, and in parts of Manitowoc, Calumet, and Fond du Lac counties. Much of Green Lake, Waushara, and Waupaca counties is underlain by them. To the north they are found as far as Shawano, in the region adjacent to Wolf River, and also at Oconto, the latter locality being 18 miles west of the present shore line.

The lacustrine clays adjoining Lake Michigan on the east and Lake Superior on the north are an important source of cream-colored brick clays. These clays have a maximum thickness along Lake Michigan of 150 feet, and are reported to be thicker along Lake Superior; at Milwaukee borings have shown them to be 100 or more feet deep. The upper beds of lacustrine clay are usually reddish brown, while the lower ones are commonly dull pinkish. The upper 1 to 5 feet may sometimes burn red, on account of the carbonate of lime having leached out. They are worked for brick and tile at many localities, among them, Green Bay, Depere, Manitowoc, Milwaukee and vicinity, and Racine. The celebrated Milwaukee cream brick are made

from deposits of this class. No physical tests of these clays have been published, but the following table shows their chemical composition:

Analyses of lacustrine or lake clays of Wisconsin.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
SiO_2	29.47	29.87	46.96	49.79	69.30	47.02	36.57	48.39	44.18
Al_2O_3	7.11	8.01	12.79	11.92	12.89	8.51	10.15	12.50	10.83
Fe_2O_3	2.58	2.78	4.40	4.60	4.90	3.20	4.06	5.40	3.30
CaO	18.18	17.21	10.15	9.30	1.02	14.28	14.55	10.88	14.05
MgO	12.25	12.22	6.27	5.18	1.35	6.25	9.63	4.82	5.91
Na_2O	0.68	0.68	0.52	0.26	1.16	0.98	0.94	0.68	0.70
K_2O	1.76	1.82	3.64	3.32	3.62	2.69	1.82	3.90	3.10
TiO_2	0.35	0.46	0.50	0.50	0.50	0.38	0.25	0.43	0.30
MnO	.....	.....	.....	.....	.....	.....	.....	Trace.	.....
H_2O, C	27.85	27.03	15.19	15.40	5.53	16.57	22.29	13.02	17.34
Total	100.19	100.08	100.42	100.27	100.27	99.88	100.26	100.02	99.75

	10.	11.	12.	13.	14.	15.	16.	17.	18.
SiO_2	43.42	59.98	47.66	41.63	43.84	40.17	39.11	47.30	38.54
Al_2O_3	10.78	16.33	14.98	8.51	7.82	9.14	11.98	12.42	10.94
Fe_2O_3	3.60	7.10	6.00	3.40	2.00	3.00	5.57	5.36	3.60
CaO	13.68	1.02	10.27	14.39	15.16	14.49	15.45	9.46	14.02
MgO	5.92	1.97	4.14	8.02	8.03	8.34	4.67	6.22	7.88
Na_2O	0.88	1.04	0.74	0.54	0.62	0.34	0.97	1.35	1.00
K_2O	3.20	4.22	2.18	2.90	2.44	3.06	3.08	3.17	2.80
TiO_2	0.40	0.58	0.56	0.35	0.33	0.35	.....	.....	0.40
MnO	Trace.	.....	0.25	0.23	.....	0.09	0.06	0.19	Trace.
H_2O, C	18.13	8.15	13.22	20.08	19.79	21.37	19.26	14.79	20.90
Total	100.01	100.39	100.00	100.05	100.03	100.35	100.15	100.26	100.08

	19.	20.	21.	22.	23.	24.	25.	26.	27.
SiO_2	33.97	52.25	45.78	43.56	36.93	38.92	37.86	36.80	43.99
Al_2O_3	9.99	9.42	9.39	11.12	8.76	7.50	7.12	9.43	10.06
Fe_2O_3	2.80	2.50	3.80	3.60	3.10	2.36	3.64	3.00	3.84
CaO	16.05	10.60	14.86	15.12	16.73	15.92	16.42	16.38	14.47
MgO	7.74	6.70	5.85	5.61	8.69	9.82	9.56	8.78	5.72
Na_2O	0.70	0.88	0.66	0.58	0.96	0.86	0.86	0.94	1.06
K_2O	2.60	2.26	3.02	3.28	2.34	2.00	1.90	2.36	3.18
TiO_2	0.28	0.28	0.40	0.40	0.30	0.25	0.20	0.23	0.33
MnO	.....	Trace.	Trace.	Trace.	.....	Trace.	Trace.	Trace.	0.18
H_2O, C	20.44	15.73	16.31	17.29	22.43	22.29	22.82	21.88	17.48
Total	100.57	100.62	100.07	100.56	100.24	99.92	100.38	99.8	100.31

1, 2. William Voigt, Boltonville, Washington County. Wisconsin Geol. Nat. Hist. Survey, Bull. No. 7, p. 270.
3, 4. Bristol Tile Works, Bristol, Kenosha County. Ibid.
5, 6. Duck Creek Brick Company, Duck Creek, Brown County. Ibid., p. 271.
7. Carl Peterson, Fredonia, Ozaukee County. Ibid.
8, 9. Green Bay Brick Company, Green Bay, Brown County. Ibid., p. 271–272.
10, 11. William Finnegan Brick Company, Green Bay, Brown County. Ibid., p. 272.
12. Edward Hartman, Marengo, Ashland County. Ibid., p. 273.
13. Burnham Brothers' West Yard, Milwaukee, Milwaukee County. Ibid.
14. Standard Brick Company, Milwaukee, Milwaukee County. Ibid.
15. Burnham Brothers' Howell Avenue Yard, Milwaukee, Milwaukee County. Ibid.
16, 17. J. W. Schultz, Oshkosh, Winnebago County. Ibid.
18. Gotlieb Gunther & Sons, Port Washington, Ozaukee County. Ibid.
19, 20. Hilker Brothers Brick Manufacturing Company, Racine, Racine County. Ibid.
21, 22. Shawano Brick and Tile Company, Shawano, Shawano County. Ibid.
23. Sheboygan Brick and Tile Company, Sheboygan, Sheboygan County. Ibid., p. 274.
24–26. August Zimbal & Sons, Sheboygan, Sheboygan County. Ibid.
27. W. D. Jordon, Shiocton, Outagamie County. Ibid.

ESTUARINE CLAYS.

These include all the clays of eastern Wisconsin which are underlain by limestone and have been modified by glacial action. They were formed at the same time and in association with the lake deposits. In fact, they resemble them so closely that the two can be mapped together. They are, however, more variable in their lime contents than the lacustrine clays. Estuarine deposits are found along the Fox, Wolf, Rock, Wisconsin, Eau Claire, Chippewa, Black, Red, Cedar, and many other rivers in the eastern, western, and southern parts of the State. The clays in these deposits are commonly thinly laminated, and show a maximum thickness of 50 to 150 feet.[a]

Besides the river deposits of this age, much later deposits of clay have formed in the valleys of many of the more important streams of to-day, especially where the tributaries are fed from regions heavily covered with glacial drift, or where they pass through rock which is largely decomposed. At the present time most of the rivers are cutting their channels deeper, and only where the streams laden with silt meander through swamp lands or discharge their loads into a lake or other reservoir are deposits of clay being formed.

The deposits which occur in the river valleys in the southwestern part of the State and those that are found throughout the glaciated region of the eastern part are very calcareous. Those in the west-central part, where limestone is not the predominant rock, are but slightly calcareous. The clays along the rivers in the extreme northern part of the State have been permeated with calcium carbonate

[a] Bull. U. S. Geol. Survey No. 65, p. 37.

derived from the limestone and marble which occur farther to the north. Limestone gravel is found abundantly in the very calcareous clays, having been transported from the limestone region either by the glaciers or the waters of the lake, and thus disseminated throughout the body of the clay. The beach deposits which occur within the body of the clay consist largely of sand and limestone gravel.

In Dunn and St. Croix counties, in the western part of the State, there are considerable quantities of pure white kaolin, which is thought to have been derived from the decomposed igneous rocks that occur northeast of this region. This kaolin is supposed to have been deposited by water prior to the first Glacial epoch. The extent of the deposits has never been accurately determined, although they are known to cover a very large area. They are interbedded with layers of sand and occur underneath a considerable thickness of till or bowlder clay. The level of these kaolin beds is about 200 feet above the estuarine deposits referred to above. It is very certain that these deposits were formed prior to the last Glacial epoch, and there are good reasons for believing that they antedate the first advance of the ice sheet. The reason for believing this is that the deposits are now covered with bowlder clay which is thought to belong to the first Glacial epoch. Further than this, the layers of clay are often crumpled, folded, and broken to a considerable depth below the surface.

The estuarine clays are worked for brick and tile, and among the localities may be mentioned Burlington, Edgerton, Madison, Merrimac, Portage, and Watertown.

The composition of these estuarine clays from different localities is given below.

Analyses of estuarine deposits contiguous to the lacustrine.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	49.39	73.36	49.26	43.68	35.81	49.57	47.57	33.48	32.66	36.65
Al_2O_3	8.99	12.83	9.25	14.37	11.19	10.84	10.49	8.95	8.73	8.39
Fe_2O_3	2.10	3.50	3.37	4.40	3.60	3.60	3.80	3.50	3.20	3.20
CaO	12.56	0.89	11.88	10.84	16.12	10.01	10.62	16.32	16.93	16.68
MgO	7.48	0.52	7.47	5.19	7.54	6.61	6.98	9.68	9.64	9.93
Na_2O	0.74	1.04	0.84	0.36	0.44	0.82	0.72	0.76	0.86	0.60
K_2O	1.90	2.30	1.52	3.76	2.64	2.50	2.44	2.08	2.30	2.61
TiO_2	0.30	0.50	0.33	0.40	0.33	0.35	0.35	0.27	0.30	0.44
MnO	Trace.	Trace.	Trace.	Trace.	.....	Trace.	.....	Trace.	Trace.	.....
H_2O, C	17.03	5.12	16.30	17.04	22.35	16.19	17.06	24.82	25.29	21.37
Total	100.49	100.06	100.22	100.04	100.02	100.49	100.03	99.86	99.91	99.87

Analyses of estuarine deposits contiguous to the lacustrine—Continued.

	11.	12.	13.	14.	15.	16.	17.	18.	19.
SiO_2	74.12	46.69	73.81	43.32	38.06	70.15	75.58	31.90	44.09
Al_2O_3	11.78	12.48	12.72	6.80	8.71	13.98	12.18	8.74	11.87
Fe_2O_3	4.50	3.60	3.40	1.28	1.20	4.80	3.30	3.00	4.00
CaO	0.96	10.28	0.52	15.50	16.28	1.18	1.01	17.06	10.29
MgO	0.85	6.57	0.81	9.62	9.96	1.03	0.84	10.63	7.15
Na_2O	0.44	0.41	0.76	0.98	0.72	1.34	1.08	0.82	0.86
K_2O	2.62	3.01	2.22	1.64	1.56	1.94	2.04	2.20	2.74
TiO_2	0.56	0.67	0.50	0.22	0.26	0.36	0.38	0.25	0.75
MnO	.....	Trace.	Volatile.	.....	.....	.....	.....	0.19	.....
H_2O, C	4.60	16.33	4.99	20.79	23.06	5.81	3.78	25.19	18.03
Total.	100.43	100.04	99.73	100.15	99.81	100.59	100.19	99.98	99.78

1. John Paddock, Baraboo, Sauk County. Wisconsin Geol. Nat. Hist. Survey, Bull. No. 7, p. 270.
2, 3. Beaver Dam Brick Works, Beaver Dam, Dodge County. Ibid.
4, 5. Burlington Brick and Tile Company, Burlington, Racine County. Ibid.
6, 7. Endeavor Brick Yard, Endeavor, Columbia County. Ibid., p. 271.
8, 9. Fort Atkinson Brick Manufacturing Company, Fort Atkinson, Jefferson County. Ibid.
10, 11. J. M. Pluck, Horicon, Dodge County. Ibid., p. 272.
12. Hubbleton, Jefferson County. Ibid.
13. Janesville, Rock County. Ibid.
14, 15. A. P. Drinker, Portage, Columbia County. Ibid., p. 273.
16, 17. Springfield Brick and Tile Company, Springfield, Walworth County. Ibid., p. 274.
18. L. H. Cordes & Co., Watertown, Jefferson and Dodge counties. Ibid.
19. Wind Lake Brick and Tile Company, Wind Lake, Racine County. Ibid.

GLACIAL CLAYS.

The glacial clays are distributed over a large part of the northern half of the State, and are all underlain by either pre-Cambrian crystalline rocks or Potsdam sandstone. These clays are of uncertain and variable thickness, but the most valuable are those which are contemporaneous with the last Glacial epoch, and such may be 40 to 50 feet thick. They are worked at several points, including Antigo, Barronnett, Edgar, Menominee, Wausau.

Analyses of glacial clays from the region not underlain with limestone and outside of the area of lacustrine clays.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	71.77	74.36	64.37	60.29	58.94	61.02	42.50	47.52	68.74	74.16
Al_2O_3	13.74	11.77	13.90	14	12.40	15.59	12.07	14.35	10.65	11.75
Fe_2O_3	3.60	4.42	5	6.80	9.20	5.12	3.90	5.60	3.16	2.80
CaO	1.23	1.14	2.80	2.84	2.91	3.22	12.72	8.51	3.81	1.31
MgO	1.17	0.69	2.15	2.73	3.16	2.49	7.23	5.66	2.73	1.17
Na_2O	1.20	1.22	1.46	1.46	1	1.26	0.56	0.58	1.94	2.18
K_2O	2.30	2.14	2.94	3.64	3.32	3.34	3.06	3.44	2.06	2.22
TiO_2	0.45	0.48	0.40	0.57	0.55	0.52	0.38	0.45	0.43	0.50
MnO	Trace.	Trace.	Trace.	Trace.	0.22	Trace.	.....	.....	0.14	0.27
H_2O, C	5	3.51	7.36	7.71	8.73	7.64	18	13.42	6.55	3.95
Total.	100.46	99.73	100.38	100.04	100.43	100.16	100.42	99.53	100.21	100.31

	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
SiO_2	73.29	65.44	64.50	63.36	50.76	62.74	70.02	70.41	69.46	69.86	70.54
Al_2O_3	11.98	13.51	13.11	14.01	34.05	17.01	14.77	13.64	14.71	13.55	13.60
Fe_2O_3	3.32	5.40	5.80	6.40	1.14	5.60	5	5.20	4.60	5.46	4.48
CaO	1.34	2.95	2.69	2.63	0.60	2.38	1.02	1.54	1.21	0.71	0.70
MgO	1.09	2.20	1.91	2.21	.....	1.84	1.03	1.49	1.56	1.43	1.41
Na_2O	1.92	1.54	1.22	1.02	0.01	0.34	0.60	1.44	1.26	1.78	1.94
K_2O	2.10	3.44	4.12	3.48	0.24	3.18	2.73	2.68	3	2.36	2.36
TiO_2	0.55	0.60	0.50	0.50	.....	0.60	0.62	0.41	0.41	0.77	1
MnO	0.14	Trace.	Trace.	Trace.	.....	.....	.....	Trace.	Trace.	Trace.	.....
H_2O, C	4.29	4.69	6.19	6.79	13	6.72	4.50	3.37	4.33	4.40	4.10
Total.	100	99.77	100.04	100.39	99.80	100.41	100.29	100.18	100.50	100.32	100.13

1, 2. J. B. Theriault, Chippewa Falls, Chippewa County. Wisconsin Geol. Nat. Hist. Survey, Bull. No. 7, p. 270–271.

3–6. East Tramway Brickyard, East Tramway, Dunn County. Ibid., p. 271.

7, 8. Lindaur & Rhode, Kaukauna, Outagamie County. Ibid., p. 272.

9–11. Central Wisconsin Pressed Brick Company, Marshfield, Wood County. Ibid.

12–14. Wisconsin Red Pressed Brick Company, Menomonie, Dunn County. Ibid.

15. Rice Lake, Barron County. Ibid., p. 273.

16, 17. River Falls Brick Company, River Falls, Pierce County. Ibid.

18, 19. Tomahawk Brickyard, Tomahawk, Lincoln County. Ibid., p. 274.

20, 21. Langenberg Brick Company, Whittlesey, Taylor County. Ibid.

CLAY-WORKING INDUSTRY.

The most important clay products made in Wisconsin are brick and tile, the latter being turned out chiefly in the southern part of the State. Paving brick or

sewer pipe are not being made at present in Wisconsin; in fact, on account of the calcareous nature of the clays, attempts to make vitrified wares in this State have been a failure.

The "kaolins" and white-burning so-called "plastic kaolins" which are found are of importance for paper making after they have been washed.

It is suggested by E. R. Buckley that the pure deposits of lacustrine clays could be used for flowerpots, cheap cuspidors, etc.

It seems doubtful, however, whether Wisconsin can ever become an important clay-producing State, partly on account of the character of the raw materials and partly because competition with neighboring States, such as Ohio, would be nearly impossible.

Wisconsin ranks twentieth among the clay-producing States, the production since 1895 having been as follows:

Value of clay products of Wisconsin from 1895 to 1901.

Year.	Value.	Rank.	Proportion of United States product.
			Per cent.
1895	$944,196	16	1.45
1896	788,995	19	1.27
1897	724,282	20	1.16
1898	877,306	20	1.02
1899	1,811,712	10	2.29
1900	1,072,179	21	1.11
1901	1,247,544	20	1.13

Value of the clay products of Wisconsin in 1900 and 1901.

	1900.	1901.
Common brick	963,461	1,151,838
Front brick	84,601	54,379
Vitrified brick	.....	(a)
Fancy brick	2,272	2,105
Fire brick	(a)	(a)
Drain tile	14,995	22,727
Fireproofing	.....	(a)
Tile (not drain)	(a)	(a)
Miscellaneous	1,800	1,400
Pottery	(a)	13,400

a Less than three producers.

RÉSUMÉ OF THE INDUSTRY.

COMMON BRICK.

Common brick are made in great quantities in all the States of the region covered by this report. Owing to the low price which the product usually brings, but little expense can be incurred in the methods of winning the clay and the manufacture of the brick, and on this account the ordinary surface clays are generally used. The process of manufacture is hurried as much as possible, but little attention being paid to the exact shade of ware produced or to obtaining a very smooth surface. In the Northern States the great spread of drift clays affords everywhere an excellent material for making common brick, while in the South the great mantle of residual clay, which is found throughout the upland region, and the sedimentary clay of the Coastal Plain surface, give opportunity for the establishment of some center of brickmaking wherever there is a market calling for the product. (Pls. III, IV, and VII.) We thus find in the vicinity of almost every one of the larger cities a thriving brickmaking industry developed. On account of their low market value common brick are rarely transported for great distances, except by water. The price per thousand varies with the locality and somewhat also with the quality of the product, but in 1901 it ranged from an average of $3.78 per thousand in South Carolina to an average of $8.13 in Nevada.

The largest brickmaking region of the Eastern United States, or, indeed in the whole country, is that of the Hudson River Valley in New York State, where nearly a billion brick are made annually and sent mostly to the New York market. Other brickmaking centers in the State are Rochester and Syracuse. In New England many brick are manufactured from the glacial clays around Boston, and in the Connecticut River Valley from the terrace clays of estuarine origin.

In New Jersey a great brickmaking area surrounds Hackensack, Bergen County, where the clays worked are very similar to those found in the Hudson River Valley of New York State. Many common brick are also molded around Sayreville from the Cretaceous clays, and at Trenton from the Columbia loams.

At Philadelphia the Columbia loams have been used for many years for making excellent red brick, while in the western part of the State, around Pittsburg, many shales or mixtures of Carboniferous shales and alluvial clay, have been found suitable for the same purpose.

The Columbia and Potomac clays support an active brickmaking industry in the vicinity of Baltimore and Washington, and the former types of clay are available at many localities farther to the south.

Many common brick are manufactured from calcareous lake clays in States of

the Mississippi Valley and those of the Great Lake region, as at Cleveland, Ohio, Detroit, Mich., Chicago, Ill., and Milwaukee, Wis. These bricks are usually buff or cream colored, but in some cases are nearly white. Many common brick are made from the drift clays of Ohio, as well as from those of Indiana and Illinois. There are important centers around Brazil, Evansville, Fort Wayne, Indianapolis, South Bend, and Terre Haute, in Indiana, and Chicago, Peoria, Quincy, and Springfield, in Illinois. In Kentucky the more important centers of common brick manufacture are Ashland, Covington, Louisville, and Paducah.

Alabama's chief brickmaking center is Montgomery, but large quantities are also made at Birmingham. In Mississippi the loams of the flood plain of the Mississippi River make an excellent red-burning brick clay and are much used. The great abundance of red residual clay all through the South has, however, interfered somewhat with the establishment of permanent plants, and many local but temporary yards have been built to supply some passing demand.

The processes used in the manufacture of common brick have improved greatly during the last fifteen years. Most yards, indeed all, with the exception of the very small ones, are operated by steam power. The soft-mud process has in many instances given way to the stiff-mud method, which, on account of its greater capacity, has great attractions, but is not adapted to as wide a range of clays. There has been a similar improvement in the drying and burning operations, sun drying having been replaced by drying in tunnels with artificial heat, and the old scove kiln by modern types, among which the continuous kiln is gaining in favor. Yet in spite of the invention of modern and improved machinery, some of the largest brickmaking regions cling to the old soft-mud process and open-air drying.

The production of common brick in the United States east of the Mississippi from 1895 to 1901 is given below:

Total value of common brick produced in the United States from 1895 to 1901.

Year.	States east of Mississippi River.	Total United States product.
1895	$23,143,772	$31,569,126
1896	24,276,620	29,664,043
1897	20,429,219	26,430,207
1898	22,881,065	30,980,704
1899	29,868,646	39,887,522
1900	25,322,478	38,621,514
1901	35,345,367	45,503,076

PRESSED BRICK.

Since these require a higher grade of raw material, the clays suitable for their manufacture are less widely distributed, and the plants are fewer in number, but the higher price which the product commands permits longer transportation to market. In former years pressed brick were made chiefly from red-burning clays, as in the case of the red Philadelphia brick. Now, however, buff-burning clays, such as No. 2 fire clays, are largely used. The reason for this is that buff is a color much liked, and, furthermore, it makes a good ground with which to mix artificial colors. Many different shades of brick are now put on the market, the color being produced either by the addition of artificial colorants or by manipulation of the kiln fires. Ornamentation is produced by varying the shape and size of the brick.

The most important works for producing pressed brick are located in those States that contain an abundance of fire clays, viz., Pennsylvania, Ohio, and New Jersey, named in the order of their importance.

Pennsylvania leads in the production of pressed brick, three types of material being drawn upon to supply the product. Around Philadelphia the well-known red brick have been made for years from the Columbia loams of that vicinity, and these have met with great favor among the architects of many Eastern cities. In the western part of the State the lower grades of fire clay are much employed for buff and other shades of front brick, and a pressed-brick works has become an adjunct to several of the large fire-brick factories. Works are located at Fallston, Monaca, Vanport, Kittanning, and other places. In the Pittsburg region a mixture of surface clays and Carboniferous shales is often used, and makes an excellent repressed or dry-pressed article.

Ohio is second in importance to Pennsylvania, and many pressed brick are made from the Carboniferous under clays at several localities, among them Akron, Shawnee, and Zanesville.

In New Jersey many buff and pressed brick are made from the Cretaceous clays around Woodbridge, Perth Amboy, and Sayreville, and find a ready sale in the markets of New York, Philadelphia, and other Eastern cities. In addition to these, large quantities of hydraulic dry-pressed brick are made from the Pleistocene clays in the vicinity of Winslow Junction, and smaller quantities are made in other parts of the State, among the localities of subordinate importance being Trenton and Belvidere.

Virginia, though of little importance as a clay-working State, produces large quantities of a white or yellowish-white front brick, which is made in large quantities from the residual clays occurring near Richmond. The product is shipped to many of the markets in the Central and Northeastern States and seems to possess

freedom from discoloration, which is a trouble many pressed-brick manufacturers have to contend with.

Wisconsin has gained some prominence as a producer of pressed brick on account of the cream brick, which have been made for many years from the calcareous lake clays at Milwaukee.

Many pressed brick are made in Illinois from the Carboniferous shales and other clays, as at Belleville and Lasalle. Considerable quantities are also produced in Indiana from Carboniferous shales and fire clays. Additional shades are often produced by mixing these with the surface clays. Among the localities where pressed brick are manufactured are Cayuga, Hillsboro, Terre Haute, Huntingburg, and Evansville.

In New York State considerable quantities of pressed brick are made from the Cretaceous clays on Staten Island, and in the western and southwestern part of the State the Devonian shales lend themselves well to the manufacturer of brick for fronts. In addition, the clays of Long Island are also used for making a dry-pressed product.

Aside from these States there is a scattered production of pressed brick reported annually from others. Many plants keep a repressing machine in order to repress their common brick to supply occasional orders, and to this is due the varying but small and persistent production of pressed brick reported by many States.

Most front brick are now made either by the stiff-mud process and repressed, or by the dry-press method of molding.

The highest average price of pressed brick in 1900 was $20 per thousand in Connecticut, but this average does not represent the highest price received for pressed brick, for those, with a highly ornamented surface, may bring as much as $40 or $50 per thousand.

The total value of pressed brick (excluding ornamental brick) produced from 1895 to 1901 was as follows:

Total value of pressed brick produced in the United States from 1895 to 1901.

Year.	States east of Mississippi River.	Total United States product.
1895	$3,458,397	$4,399,367
1896	2,638.016	3,390,941
1897	3,194,065	3,855,033
1898	2,805,073	3,572,385
1899	3,588,189	4,767,343
1900	3,062,338	3,864,670
1901	3,335,154	4,709,737

FIREPROOFING.

The active construction of many modern fireproof buildings in all the larger cities at the present time had led to the widespread use of hollow brick or fireproofing for the protection of steel girders and the construction of floor arches and partitions. Some idea of the expansion of this industry may be gained from a statement made in the clay report issued by the New Jersey geological survey in 1878, in which fireproofing is referred to as a new kind of brick which was being experimented with at that time. In 1900 the value of the fireproofing produced in the United States was $1,820,214, and most of this came from three or four States. The clays used for fireproofing are either common brick clays or impure fire clays, and consequently the material can be manufactured in almost any State, which accounts for the long list of producers, although they are by no means all large ones. Certain States, however, as New Jersey, Ohio, and Indiana, produce great quantities of this material to supply the large markets located in their vicinity, and in such States there are large factories whose output is entirely fireproofing material. More recently these factories have been turning their attention to the manufacture of conduits for electrical subways, since these can be made on the same type of machine and from a similar mixture of clays. These are made in large quantities now by some of the plants in New Jersey.

The total value of the fireproofing produced in the Eastern States from 1895 to 1901 is as follows:

Total value of fireproofing produced in the United States from 1894 to 1901.

Year.	States east of Mississippi River.	Total United States product.
1894	$478,827	$514,637
1895	660,626	741,626
1896	1,378,860	1,706,504
1897	1,890,565	1,979,259
1898	1,571,812	1,900,642
1899	1,555,813	1,665,066
1900	1,610,769	1,820,214
1901	2,874,290	1,820,269

ROOFING TILES.

Roofing tiles are made at few localities, but the industry is slowly expanding, although the number of plants is not increasing much. Three styles of tile are made, viz, the Roman, shingle, and interlocking. Each company making roofing tiles usually confines itself to one type, which it most earnestly advocates the use of.

Two factories are located in New York, two in Illinois, one in Maryland, one in Ohio, and one in Georgia. The tiles are usually red and are sometimes glazed. Some are vitrified, while others are not.

TERRA COTTA.

The use of terra cotta for exterior decoration and as a substitute for stone has created a great demand for the material, especially in the larger cities, where building operations are active. Factories are located in a number of States, but most of the product comes from New York, New Jersey, and Illinois. The general character of the ware is much the same, consisting usually of a mixture of fire clays, which burn to a strong buff, or sometimes a red, if more ferruginous clays are used. The color of the ware is contained in the slip, which is sprayed over the surface in the form of a thin film. Many shades are made, the color applied being frequently put on for the purpose of matching the building stone which is to be used in the same building with the terra cotta. There are a number of firms in New Jersey manufacturing terra cotta which obtain their supply of material from the neighboring clay pits. The same material is used by some of the New York manufacturers, although those in the southwestern part of the State employ Devonian shales as well.

In Pennsylvania considerable terra cotta is made in the eastern part of the State from New Jersey clays, while a large factory is in operation at Evanston, Ill. Very little is made in Ohio. Other producing States are Maryland, Georgia, Kentucky, and Michigan. The value of the ornamental terra cotta produced in the United States in 1901 was $3,367,982, of which $2,874,290 was produced east of the Mississippi.

ENAMELED BRICK.

The enameled-brick industry is a young one in the United States and for many years has had to compete with the prejudice that existed in favor of the imported English enameled materials. At the present day it can probably be said, however, that the domestic product is in many cases fully equal to the imported material. Bricks of this type are made in Pennsylvania, New Jersey, Maryland, Illinois, and Georgia.

FLOOR TILES.

Those made in the United States are of two types, viz, tiles of solid color and encaustic tiles. The tile first named is of the same color throughout, while in the latter the color or design forms only the upper portion of the tile, the remainder of the body being formed of some buff burning clay. The tiles are always made by the dry-press process, and while the solid-color ones are molded in many different forms, the encaustic tiles are usually square. The number of shades and colors produced is so great that artificial methods of coloration have to be resorted to. Clay tiles have gained great favor as a flooring material, and come into active competition with slate

and marble. They possess the advantage of being harder, more durable, and capable of being worked into a greater number of designs and colors. Many factories produce both styles of these tiles, and supply not only the domestic demand, but also export their product, which is in some cases shipped as far as Australia.

Floor tiles are manufactured at Trenton, N. J., Pittsburg, Pa., Zanesville, Ohio, Indianapolis, Ind., and other localities. They are commonly made from a mixture of clays and shales, those from the Carboniferous formations being perhaps the most used.

GLAZED TILES.

Glazed tiles for wall decoration are produced in several States. The body of these has to be necessarily much whiter and more porous than that of floor tiles, and they are often made from the higher grades of clay, such as kaolin. The surface is sometimes pressed in relief, and the glaze may be either colorless, colored, or opaque. There is considerable rivalry between the different manufacturers to produce new colors and designs, and the number of them is consequently very great.

Hand-painted tiles and cloissonnée ones are very little made, if at all, in the United States. The distribution of glazed-tile factories bears no relation to the distribution of the raw materials, for these form but a small proportion of the expense of manufacture.

Glazed tiles are made at Chelsea, Mass.; Trenton, N. J.; Morrisville and Beaver Falls, Pa.; Covington, Ky.; Old Bridge and Perth Amboy, N. J.; Tarrytown, N. Y.; and Indianapolis, Ind.

VITRIFIED BRICK.

The production of vitrified brick in the United States is probably not exceeded by that of any other country in the world, and in the Middle States especially it has developed into an industry of vast extent. This is due partly to the absence of other cheap paving materials and to the excellent qualities of brick pavements when subjected to moderate traffic, as well as to the presence in the Central States of suitable raw materials so situated that the product can be turned out rapidly and economically.

The total value of the paving brick produced in the States lying east of the Mississippi from 1895 to 1901 is given below:

Total value of paving brick produced in the United States from 1894 to 1901.

Year.	States east of Mississippi River	Total United States product.
1894	$2,739,849	$3,711,073
1895	2,672,305	3,130,472
1896	2,442,939	2,794,585
1897	2,729,583	3,582,037
1898	2,923,715	4,016,822
1899	3,835,955	4,750,424
1900	3,636,365	4,764,124
1901	4,321,178	5,484,134

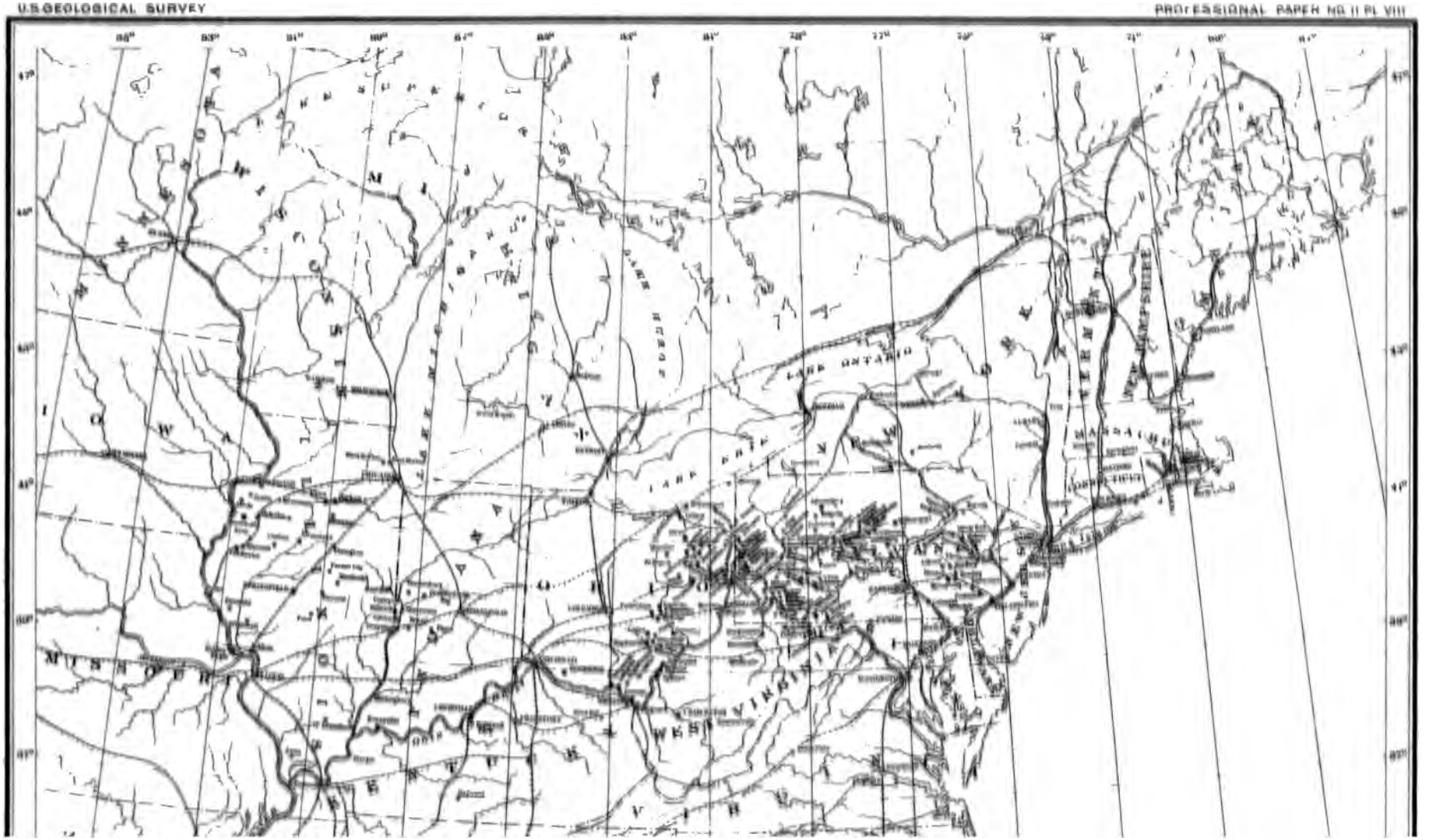
The output for 1901 was as follows:

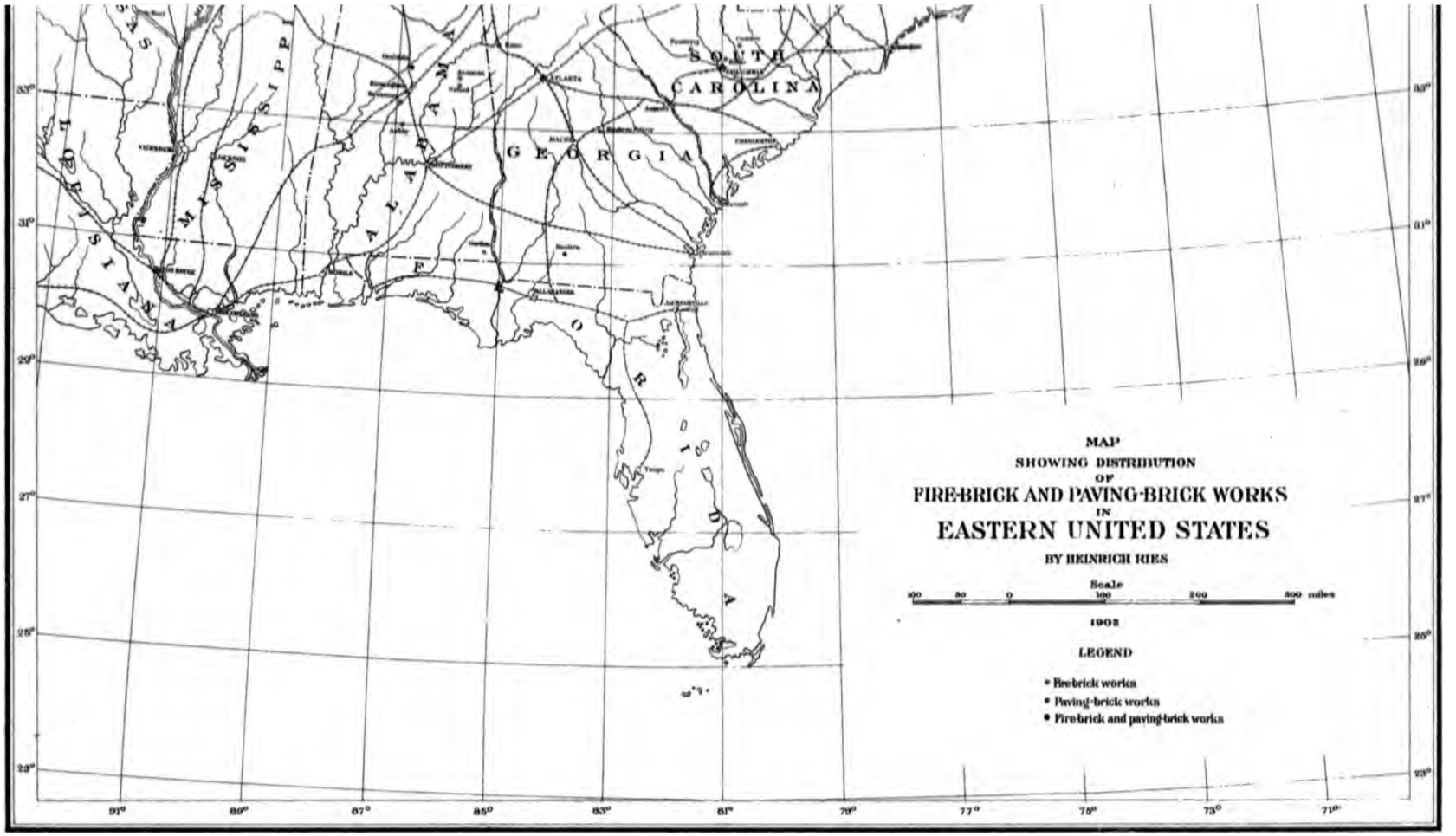
Production of paving brick east of Mississippi in 1901.

State.	Quantity.	Value.	Average price per thousand.
	Thousands.		
Alabama	(a)	(a)	$11.00
Georgia	(a)	(a)	7.69
Illinois	99,572	899,454	9.03
Indiana	31,468	320,221	10.18
Kentucky	(a)	(a)	12.71
Maine	(a)	(a)	20.02
Maryland	(a)	(a)	15.00
Michigan	(a)	(a)	12.30
New Jersey	2,251	22,024	9.78
New York	29,950	343,343	11.46
North Carolina	(a)	(a)	10.00
Ohio	175,757	1,443,537	8.21
Pennsylvania	73,498	670,081	9.12
Tennessee	6,624	67,129	10.13
West Virginia	62,805	555,389	8.84

a Where the output is contributed by less than three firms the figures are not given.

Although West Virginia was the cradle of the paving-brick industry, Ohio now leads the States in the production of this class of ware, but large quantities also come from Illinois, Pennsylvania, West Virginia, New York, and Indiana, named in the order of their importance. The general distribution of paving-brick works is shown on the map (Pl. VIII). Most of the bricks of this class are made from fine-grained ferruginous shales, these being found to yield the best results. In some cases a certain quantity of low-grade fire clay is added—in fact during the early stages of the industry, fire clays alone were considered necessary. The method of manufac-


IOWA
MINNESOTA
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
WEST VIRGINIA
VIRGINIA


MAP
SHOWING DISTRIBUTION
OF
FIRE-BRICK AND PAVING-BRICK WORKS
IN
EASTERN UNITED STATES
BY HEINRICH RIES
Scale
50 miles
1902
LEGEND
Fire-brick works
Paving-brick works
Fire-brick and paving-brick works
SOUTH CAROLINA
GEORGIA
ATLANTA
MISSISSIPPI
LOUISIANA
ALABAMA
FLORIDA
91°
89°
87°
85°
83°
81°
79°
77°
75°
73°
71°
35°
33°
31°
29°
27°
25°
23°

ture has gone through various experimental stages, but the stiff-mud method is now preferred by most paving-brick manufacturers on account of its greater capacity.[a]

Much discussion has taken place in recent years regarding the adoption of a standard method of testing paving brick, and also of the effect of the method of manufacture on the abrasive resistance of the product. This subject has been one of special investigation by a committee appointed by the National Brickmakers' Association, and their report deals with the correct method of making tests so as to insure reliable and uniform results.

DRAIN TILE.

An examination of the statistics of drain tile production are of interest as showing the agricultural conditions of the State in which they are made. Since they can be manufactured from ordinary brick clays, they are produced chiefly in response to a local demand. As will be seen from the statistics given annually in the reports of the United States Geological Survey, Ohio, Illinois, Indiana, and Michigan are the most important producers, though large quantities are also made in New Jersey and New York. The variation in the quantity produced by any one State from year to year is due to special and irregular local demands. Any manufacturer making brick by the auger stiff-mud process can, by changing the die, produce tile instead of brick whenever there is a call for the material.

The tile are made of varying diameters, from 2 up to 6 inches, but commonly about 3 or 4.

Value of drain tile produced from 1894 to 1901.

Year.	States east of Mississippi River.	Total United States product.
1894	$4,898,931	$5,803,162
1895	3,113,919	3,450,961
1896	2,326,508	2,613,513
1897	2,176,932	2,623,305
1898	1,936,582	3,115,318
1899	3,141,607	3,682,394
1900	2,483,387	2,976,281
1901	2,465,875	3,143,001

SEWER PIPE.

Sewer pipe are made from a clay which will yield a vitrified product at moderate temperatures, and shale therefore usually gives the best results. It is consequently not surprising to find Ohio the main producer, leading all the other States by a very large margin. The sewer-pipe factories in that State, especially those near Akron,

[a] For a discussion of the manufacture of paving brick see pamphlet by H. A. Wheeler on Vitrified Paving Brick, Indianapolis, 1895. For tests of paving brick see Ries, H., The clay-working industry of the United States in 1896: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. V (continued), p. 1111.

are operated on a gigantic scale, and much of the product is shipped to neighboring States.

Next to Ohio, Pennsylvania, Indiana, and Illinois produce considerable quantities of sewer pipe, and small amounts come from other States.

The production for 1894–1901 is given below:

Value of sewer pipe produced in the United States from 1894 to 1901.

Year.	States east of Mississippi River.	Total United States product.
1894	$5,150,497	$5,989,923
1895	3,573,982	4,482,577
1896	3,845,436	4,588,503
1897	3,187,615	4,069,534
1898	2,209,032	3,791,057
1899	2,646,599	4,560,334
1900	3,692,854	5,842,562
1901	4,221,018	6,736,969

FIRE BRICK.

The production of fire brick has shown a phenomenal increase during the last three years, most of the production having come from the States lying east of the Mississippi. This increased output can be seen from the following table, in which the production since 1894 is given:

Value of fire brick produced in the United States from 1894 to 1901.

Year.	States east of Mississippi River.	Total United States product.
1894	$4,221,665	$4,762,820
1895	4,587,738	5,279,004
1896	4,461,785	4,944,723
1897	3,712,875	4,094,704
1898	5,039,269	6,093,071
1899	7,886,866	8,641,882
1900	8,810,360	9,830,517
1901	8,523,989	9,870,421

The important position which the Eastern States occupy as producers of fire brick is due not alone to the presence of refractory clays, but also to the development of metallurgical industries in those areas. In 1900 Pennsylvania alone produced over four and a half million dollars' worth of fire brick, while Ohio and New Jersey each supplied over one million dollars' worth. This great output is occasioned by an active demand, and will no doubt continue as long as the United States is the leading producer of iron and steel. Many others are consumed by other branches of

the metallurgical industries. Quantity alone is not called for, however, but in addition the manufacturer has to produce a variety of grades and many different shapes.

A brick can not be produced which will satisfactorily meet all conditions. Some bricks are exposed to high heat alone, others must resist abrasion rather than excessive heat. Again, resistance to corrosion at high temperatures is necessary, and even here it is sometimes an acid, at others a basic, brick that is required.

Comparatively few analyses or tests of refractoriness have been published. Of the former a few are collected here, and such indicate bricks of rather siliceous character:

Analyses of fire brick.[a]

	1.	2.	3.	4.	5.	6.	7.	8.
SiO_2	52.87	52.48	78.08	58.97	59.98	71.55	58.75	65.24
Al_2O_3	40.28	40.65	17.89	32.969	36.009	25.09	36.79	28.875
TiO_2	2.44	1.67	.81	1.62	1.70	1.05	1.75	1.67
Fe_2O_3	1.32	1.99	.97	1.97	1.911	1.28	1.39	2.71
CaO	1.41	.26	.56	.12	.10	.65	.11	.09
MgO	.396	.299	.35	.503	Tr.	.364	.301	.338
Alkalies	.98	2.79	2.115	1.277	1.174	.384	.913	1.312
Total	99.696	100.139	100.775	100.429	100.875	100.368	100.004	100.235

[a] Second Pennsylvania Geol. Survey, Rept. MM., p. 269. For a series of tests see ibid., p. 271 et seq.

1. Clearfield fire brick, Clearfield County, Pa.
2. Queens Run fire brick, Clinton County, Pa.
3. Maxwells, Bradley & Co., Layton station, Pa.
4. Savage Fire Brick Works, Keystone Junction, Somerset County, Pa.
5. Mount Savage fire brick, Union Mining Company, Mount Savage, Md.
6. Hall & Sons' No. 1 fire brick, Perth Amboy, N. J.
7. Hyzer & Lewellen's, made from Woodbridge fire clay.
8. Soisson & Glover's fire brick, Connellsville.

Silica brick and basic brick constitute special types, which are manufactured to a small extent.

There are many fire-brick works scattered over Pennsylvania, Ohio, and New Jersey, as can be seen from the map on Pl. VIII, and consequently the furnaces in these States rarely send any distance for fire brick. Many furnaces in eastern Pennsylvania, therefore, draw on the New Jersey factories to a large extent.

Fire brick are also manufactured from local clays in West Virginia, Indiana, Illinois, Kentucky, Tennessee, Alabama, Georgia, North Carolina, South Carolina, and Maryland. Those produced in other States, viz, Florida, Wisconsin, Michigan, New Hampshire, Maine, New York, Massachusetts, and Connecticut are made almost entirely from clays obtained from neighboring States. Many brick are shipped by water, and even rail, to Mexico and Canada.

POTTERY.[a]

The pottery industry of the United States has shown a most phenomenal growth, and the product now embraces a number of grades, including red earthenware, stoneware, porcelain, white earthenware, belleek, majolica, etc. The commoner grades are usually made at small potteries scattered over the country, and supported by local trade, but the factories making the highest grades of ware are often grouped around a few localities, which have been chosen on account of their being transportation centers. Their distribution is shown on Pl. IX.

The increase in the total value of the product is shown by the following table:

Total value of pottery products from 1896 to 1901.

Year.	States east of Mississippi.	Total United States product.
1896	$6,351,240	$7,455,627
1897	8,880,122	10,309,209
1898	13,381,750	14,589,251
1899	16,677,562	17,250,250
1900	19,189,356	19,798,670
1901	21,865,908	22,463,860

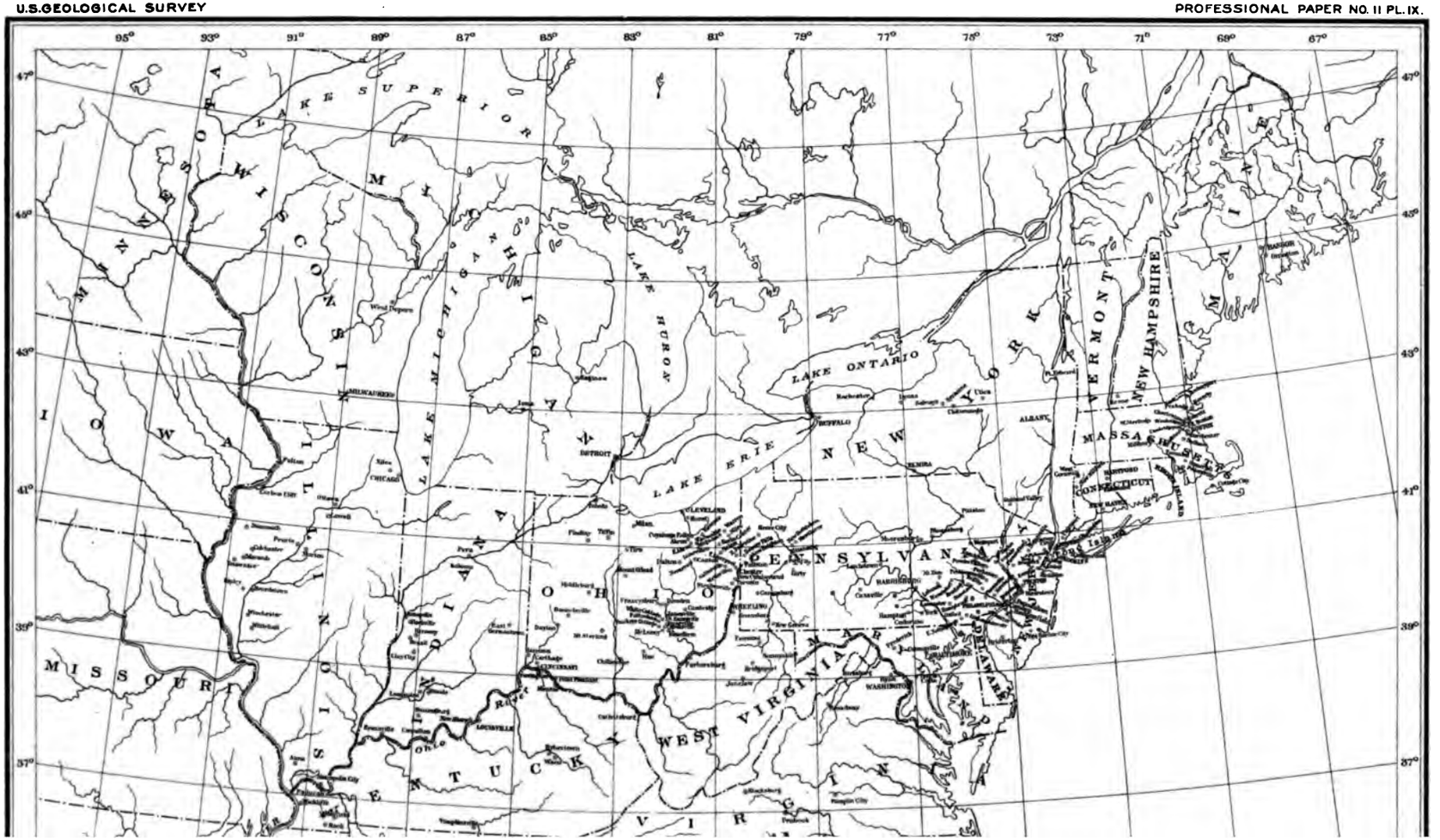
From the above figures it will be seen that most of the pottery produced in this country comes from the region lying east of the Mississippi. This is due partly to a greater demand within this area, and also due to the presence of raw materials and manufacturing facilities.

The rank of the more important States has not changed much during the past six years, as is indicated below.

Rank of States in value of pottery from 1896 to 1901.

Rank.	1896.	1897.	1898.	1899.	1900.	1901.
1	Ohio	Ohio	Ohio	Ohio	Ohio	Ohio.
2	New Jersey	New Jersey	New Jersey	New Jersey	New Jersey	New Jersey.
3	Pennsylvania	Pennsylvania	Pennsylvania	Pennsylvania	Pennsylvania	Pennsylvania.
4	Illinois	Illinois	Illinois	Illinois	New York	New York.
5	West Virginia	West Virginia	West Virginia	New York	Illinois	West Virginia.
6	New York	Minnesota	New York	West Virginia	West Virginia	Illinois.
7	Massachusetts	Maryland	Minnesota	Maryland	Maryland	Indiana.
8	Indiana	Massachusetts	Maryland	Indiana	Indiana	Maryland.
9	Kentucky	Indiana	Indiana	Massachusetts	Minnesota	Minnesota.
10	Texas	New York	Massachusetts	Minnesota	Massachusetts	Massachusetts
11	Missouri	Kentucky	Kentucky	Kentucky	Kentucky	Kentucky.
12	Connecticut	Connecticut	Connecticut	Texas	Texas	Connecticut.

[a] An excellent historic account of the industry is contained in E. A. Barber's Pottery and Porcelain of the United States. See also Ries, H., The pottery industry of the United States: Seventeenth Ann. Rept. U. S. Geol. Surv., Pt. III (continued), p. 842.


95° 93° 91° 89° 87° 85° 83° 81° 79° 77° 76° 73° 71° 69° 67°
47° 45° 43° 41° 39° 37°
LAKE SUPERIOR
MINNESOTA
WISCONSIN
MICHIGAN
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
IOWA
ILLINOIS
INDIANA
OHIO
KENTUCKY
WEST VIRGINIA
VIRGINIA
MARYLAND
DELAWARE
NEW YORK
PENNSYLVANIA
NEW JERSEY
CONNECTICUT
MASSACHUSETTS
VERMONT
NEW HAMPSHIRE
MISSOURI
Ohio River
Milwaukee
Chicago
Detroit
Buffalo
Cleveland
Pittsburgh
Albany
Boston
Philadelphia
Washington
Baltimore
Louisville
Cincinnati
Columbus
Wheeling
Harrisburg
Trenton
Hartford
New Haven
Providence
Portland
Rochester
Syracuse
Utica
Troy
Schenectady
Binghamton
Elmira
Scranton
Reading
Lancaster
Wilmington
Richmond
Norfolk
Charleston
Lexington
Frankfort
Nashville
Memphis
Peoria
Springfield
Indianapolis
Fort Wayne
Toledo
Akron
Canton
Youngstown
Erie
Altoona
Williamsport
Wheeling
Parkersburg
Huntington
Charleston
Lynchburg
Roanoke
Petersburg
Newport News
Portsmouth
Chesapeake
Hampton
Annapolis
Dover
Salisbury
Ocean City
Atlantic City
Camden
Newark
Jersey City
Paterson
Elizabeth
Trenton
Princeton
New Brunswick
Perth Amboy
Long Branch
Asbury Park
Bridgeport
Stamford
Norwalk
New Haven
Hartford
New London
Waterbury
Meriden
Middletown
Willimantic
Providence
Pawtucket
Woonsocket
Newport
Fall River
New Bedford
Taunton
Brockton
Quincy
Boston
Cambridge
Somerville
Lowell
Lawrence
Haverhill
Salem
Gloucester
Newburyport
Portsmouth
Dover
Manchester
Nashua
Concord
Keene
Claremont
Rutland
Burlington
Montpelier
Barre
Bennington
Brattleboro
Springfield
Northampton
Holyoke
Chicopee
Pittsfield
North Adams
Greenfield
Amherst
Worcester
Fitchburg
Leominster
Gardner
Clinton
Marlborough
Framingham
Natick
Wellesley
Newton
Brookline
Waltham
Watertown
Belmont
Arlington
Medford
Malden
Everett
Chelsea
Revere
Winthrop
Hull
Cohasset
Scituate
Marshfield
Duxbury
Plymouth
Kingston
Middleboro
Attleboro
Norton
Mansfield
Foxboro
Sharon
Canton
Milton
Dedham
Needham
Wellesley
Weston
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Carlisle
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Woburn
Stoneham
Melrose
Wakefield
Reading
North Reading
Wilmington
Tewksbury
Billerica
Chelmsford
Tyngsboro
Dunstable
Pepperell
Groton
Ayer
Shirley
Harvard
Bolton
Berlin
Hudson
Marlborough
Southborough
Westborough
Northborough
Shrewsbury
Boylston
West Boylston
Sterling
Lancaster
Clinton
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Canton
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Foxboro
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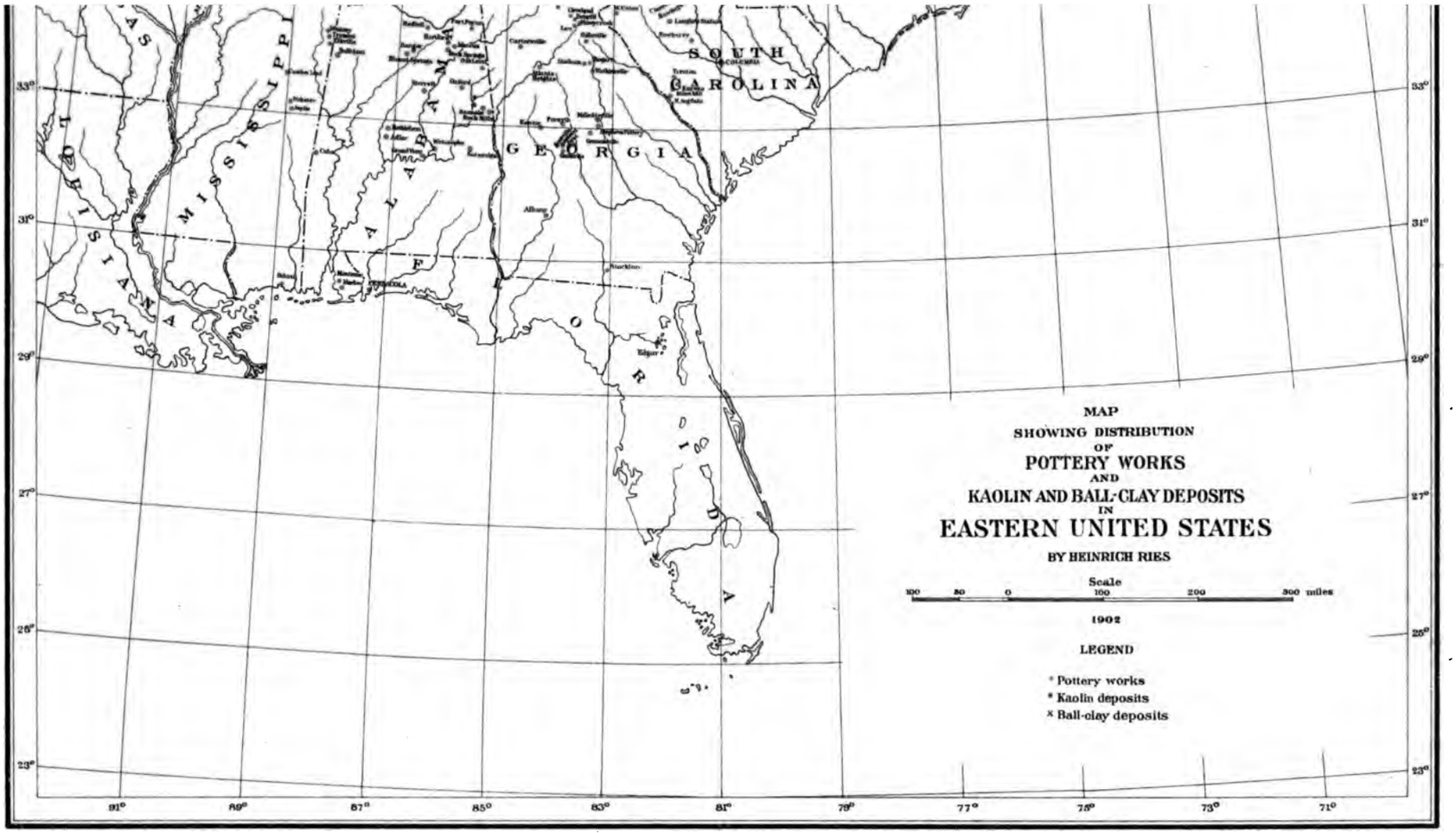
Sterling
Lancaster
Clinton


MAP
SHOWING DISTRIBUTION
OF
POTTERY WORKS
AND
KAOLIN AND BALL-CLAY DEPOSITS
IN
EASTERN UNITED STATES
BY HEINRICH RIES
Scale
100 50 0 100 200 300 miles
1902
LEGEND
° Pottery works
* Kaolin deposits
x Ball-clay deposits
SOUTH CAROLINA
GEORGIA
ALABAMA
MISSISSIPPI
LOUISIANA
FLORIDA
33°
31°
29°
27°
25°
23°
91°
89°
87°
85°
83°
81°
79°
77°
75°
73°
71°

The States ranking first and second in the production of several kinds of ware in 1901 were:

States ranking first and second in production of certain wares in 1901.

Product.	First.	Second.
Red earthenware	Ohio	Massachusetts.
Stoneware	do	Illinois.
C. C. ware	do	New Jersey.
White granite	do	Do.
Semivitreous	do	Do.
China	New Jersey	New York.
Sanitary ware	do	Ohio.
Electrical supplies	do	New Jersey.

The total value of pottery products produced by the Eastern States in 1900 and 1901 was as follows:

Value of pottery in Eastern States in 1900 and 1901.

States.	1900.		1901.	
	Value.	Per cent of total United States product.	Value.	Per cent of total United States product.
Ohio	$8,573,323	43.30	$10,048,561	44.73
New Jersey	5,263,651	26.59	5,900,073	26.26
Pennsylvania	1,390,873	7.03	1,665,012	7.41
Illinois	776,773	3.92	682,449	3.04
New York	1,165,325	5.89	1,077,360	4.80
West Virginia	631,841	3.19	858,642	3.82
Maryland	436,617	2.21	333,480	1.48
Indiana	325,900	1.65	531,371	2.37
Massachusetts	238,724	1.21	281,368	1.25
Kentucky	131,497	.66	139,697	.62
Connecticut	61,250	.31	91,200	.41
Tennessee	49,655	.25	64,093	.29
Michigan	34,317	.17	44,865	.20
Alabama	20,296	.10	18,362	.08
Georgia	24,383	.12	17,230	.07
North Carolina	18,863	.10	20,037	.09
Mississippi	14,452	.07	4,779	.02
District of Columbia	10,873	.06	12,879	.06
South Carolina	17,633	.09	11,872	.05
Virginia	13,110	.02	4,047	.02
Wisconsin			13,400	.06

Red earthenware.—Most of the pottery classed under this head represents the lowest form of ware made, such as flower pots. Some decorated earthenware is

made from common clays, especially in Ohio, the products including jardinières and ornamental objects, often covered with a slip or glaze, and sometimes decorated in relief designs. Red earthenware is manufactured in large quantities in Ohio, Pennsylvania, and Massachusetts, but aside from these the amount produced is usually small and made to supply a local demand.

STONEWARE. In 1900 stoneware was manufactured in most of the States lying east of the Mississippi River, but nearly all of the product was supplied by Ohio, Illinois, and Pennsylvania, for the reason that those States contain materials eminently suited for that class of goods.

The goods made with a stoneware body are intended mostly for domestic use, and consist of crocks, jugs, jars, and various kitchen utensils, which can be placed directly on the stove and used for cooking. Stoneware for chemical purposes forms a special grade of product, since it must resist corrosion by acids and rapid changes of temperature. Several firms have given their attention to the production of this material which formerly was obtainable only from abroad, and it is now made in Philadelphia, Pennsylvania, and to some extent in Ohio; but though the American goods have won a high reputation they do not yet supply the entire demand.

ORNAMENTAL GOODS. Ornamental goods with stoneware body partake chiefly of the form of jardinières and to some extent vases. They are produced in Ohio. Attempts have been made to introduce the manufacture of Rhenish ware, but the industry has not yet gained a strong foothold, and most of the articles of this class are still imported.

WHITE EARTHENWARE AND CHINA. These two classes of ware form the greater proportion of pottery goods manufactured in the United States and come into active competition with imported ware, especially with those of English make. Indeed the industry was probably introduced by English potters.

There is a greater concentration in the case of this branch of the industry than in others, most of the potteries being located at East Liverpool, Ohio, and Trenton, N. J. The importance of these two pottery centers was well shown in Mineral Resources for 1900, where it is pointed out that the value of the product for the two localities in 1900 was as follows:

Trenton, N. J.	$5,575,000
East Liverpool, Ohio	4,004,716
Total	9,579,716

From this it is seen that the output of these two localities alone represents 67.8 per cent of the total United States production. Both cities are centrally located, so that the clays, flint, spar, and coal can be easily brought in and the goods shipped over various lines of railroad.

The white ware manufactured is chiefly for table and toilet purposes, and to a smaller extent for ornamental use. The product is chiefly plain white, but some is

decorated either over or under the glaze by printing. Chromo-lithographic decoration is still but little used in the United States. The wares produced are largely for hotel use, and there is room for improvement in the weight.

Within recent years the manufacture of sanitary ware, begun at Trenton in 1853, has been developed to an extraordinary degree and is fully equal in quality to material formerly much imported.

In addition to the white earthenware centers already mentioned there are a number of other localities whose output is not inconsiderable. These include New York City, N. Y., Baltimore, Md., Wheeling, W. Va., Sebring, Ohio, Kittanning, Pa., and Peoria, Ill.

Semivitreous porcelain.—This includes a grade of white ware which is partially vitrified and manufactured in New York, New Jersey, and Ohio.

China.—The term "china" refers to vitrified white ware, which is manufactured at only a few factories, these being at Syracuse and Greenpoint, N. Y.; Trenton, N. J., and East Liverpool, Ohio. It is translucent and often thinner than white earthenware. Very little hard porcelain is as yet manufactured in the United States, and there is a promising field for development along this line.

Belleek or egg-shell ware is a translucent porcelain with very thin and highly feldspathic body of cream color. The ware is commonly made by "casting" the slip in the molds. The articles made are chiefly of ornamental character, but table articles of smaller sizes are also produced in this manner. Most of the Belleek ware manufactured in the United States comes from Trenton, but smaller quantities are produced in Ohio.

Electrical supplies.—The great development of the electrical industry calls for vast quantities of insulators, and several firms have gone extensively into the manufacture of this class of goods. The conditions of use call for a vitrified body, so that no absorption of moisture can take place. Electrical goods are now made at Trenton, N. J., Syracuse and Victor, N. Y., and East Liverpool, Ohio. They include a variety of forms, most of which are made for some special purpose.

Art pottery.—This deserves special mention, because of the uniqueness of the wares produced at several localities. Foremost among the wares of this class stands the Rookwood pottery, manufactured at Cincinnati, Ohio, since 1889. The ware is decorated entirely by hand painting, and shows an intermingling of various rich shades of brown, green, yellow, and other colors. A somewhat similar ware is made in great quantities at Zanesville, Ohio, by the J. B. Owens pottery. The Lonhuda ware, made at Steubenville, Ohio, represents another type.

The Grueby faience, with its dull enamel surface and greens and yellows, represents still another unique product of the American potters' art. Clock cases are made specially at Baltimore, Md., jardinières at Wheeling, W. Va., and fern dishes and jardinières at Trenton, N. J., and East Liverpool, Ohio.

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